NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3052

THE EFFECT OF VERTICAL CHINE STRIPS ON THE PLANING CHARACTERISTICS OF V-SHAPED PRISMATIC SURFACES HAVING ANGLES OF DEAD RISE OF 20° AND 40°

By Walter J. Kapryan and George M. Boyd, Jr.

Langley Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

The effect of vertical chine strips on the planing characteristics of two prismatic surfaces having angles of dead rise of 20° and 40° has been determined as part of a general research investigation on planing surfaces. Wetted lengths, resistance, and center-of-pressure location were determined at speed coefficients up to 25.0, load coefficients up to approximately 80.0, and trims up to 30°. In addition, comparisons of the more important planing characteristics are made with those for related surfaces having angles of dead rise of 0°, 20°, and 40°, and for surfaces having angles of dead rise of 20° and 40° with horizontal chine flare. These comparisons show that vertical chine strips are a more effective means of increasing the lift of a given surface than horizontal chine flare is. This increase in lift, however, is accompanied by a substantial increase in drag so that the lifting efficiency of the vertically flared surface is comparable to one having horizontal chine flare.

INTRODUCTION

A general program of research on the planing characteristics of a series of related prismatic surfaces has been undertaken by the National Advisory Committee for Aeronautics and is described in reference 1. The primary objective of this program is an extension of the range of experimental data on planing surfaces to cover the high trims and loads of significance in the design of high-speed water-based aircraft.

As part of this general program a detailed experimental investigation has been made to determine the effect of vertical chine strips on the planing characteristics of prismatic surfaces having angles of dead rise of 20° and 40°. Vertical chine strips are of particular interest because of their favorable effects on spray characteristics and on lift of prismatic surfaces.

This paper presents lift and drag coefficients and center-of-pressure location for these two models for Froude numbers up to 25.0, trims up to 30°, and wetted-length—beam ratios up to 7.0. A general comparison of the data for surfaces with vertical chine strips is made with data for simple surfaces having angles of dead rise of 0°, 20°, and 40° (refs. 2 and 3) and for surfaces having angles of dead rise of 20° and 40° with horizontal chine flare (refs. 1 and 4).

SYMBOLS

b beam of planing surface including chine strips, 0.344 ft

b' beam of planing surface exclusive of chine strips, 0.333 ft

C_{D_b} drag coefficient based on square of beam, $\dfrac{R}{\frac{\rho}{2}V^2b^2}$

C_{D_S} drag coefficient based on principal wetted area, $\dfrac{R}{\frac{\rho}{2}V^2S} = \dfrac{C_{D_b}}{l_m/b}$

C_f skin-friction coefficient, $\dfrac{F}{\frac{\rho}{2}S_f{V_m}^2} =$

$$\frac{\cos\beta\cos^2\tau}{\frac{l_m}{b}\cos\tau - C_{L_b}}\left(C_{D_b} - C_{L_b}\tan\tau\right)\frac{\frac{l_m}{b}}{\frac{l_m}{b}\frac{b'}{b} + 2\cos\beta\frac{l_c}{b}\frac{h+t}{b}}$$

C_{L_b} lift coefficient based on square of beam, $\dfrac{\Delta}{\frac{\rho}{2}V^2b^2} = 2\dfrac{C_\Delta}{{C_V}^2}$

C_{L_S} lift coefficient based on principal wetted area, $\dfrac{\Delta}{\frac{\rho}{2}V^2S} = \dfrac{C_{L_b}}{l_m/b}$

C_R resistance coefficient, R/wb^3

C_V speed coefficient or Froude number, $V/\sqrt{gb}$

C_Δ load coefficient, Δ/wb^3

F	friction, parallel to planing surface, lb
g	acceleration due to gravity, 32.2 ft/sec^2
h	inside depth of chine strip, ft
l_c	chine wetted length, ft
l_k	keel wetted length, ft
l_m	mean wetted length, $\frac{l_k + l_c}{2}$, ft
l_p	center-of-pressure location (measured along keel forward of trailing edge), $\frac{M}{\Delta \cos \tau + R \sin \tau}$, ft
M	trimming moment about trailing edge of model at keel, ft-lb
R	horizontal resistance, lb
R_e	Reynolds number, $V_m l_m/\nu$
S	principal wetted area (bounded by trailing edge, chines, and heavy spray line) projected on plane parallel to keel, $l_m b$, sq ft
S_f	actual wetted area aft of heavy spray line, $\frac{l_m b'}{\cos \beta} + 2l_c(h + t)$
t	thickness of chine strip, ft
V	horizontal velocity, fps
V_m	mean velocity over surface, $\sqrt{V^2\left(1 - \frac{C_{L_b}}{\frac{l_m}{b} \cos \tau}\right)}$
w	specific weight of water, lb/cu ft
β	angle of dead rise, deg
Δ	vertical load, lb
ν	kinematic viscosity, ft^2/sec

ρ mass density of water, slugs/cu ft

τ trim (angle between keel and horizontal), deg

DESCRIPTION OF MODELS

The models and their cross sections with pertinent dimensions are shown in figures 1 and 2. The basic angles of dead rise are 20° and 40°, respectively, and the angles of dead rise to the inner edge of the chine strips are 16° and $32^{\circ}\ 47'$, respectively. The depths of the chine strips are such that the latter angles are the same as those of the surfaces having basic angles of dead rise of 20° and 40° with horizontally flared chines (refs. 1 and 4). The addition of the chine strips increased the over-all beam of the models from 4 inches to 4.125 inches. The coefficients used throughout this paper, therefore, are based on a beam of 4.125 inches. A detailed description of the construction and finish of the brass models is presented in reference 1.

APPARATUS AND PROCEDURES

The apparatus, procedures, and instrumentation used for this investigation are described in references 1 and 5. A diagram of the model and towing gear is presented in figure 3. Wetted lengths were determined from underwater photographs and from visual readings in the manner described in reference 1. A typical underwater photograph is shown as figure 4.

The aerodynamic forces on the model and towing gate were held to a minimum by use of the wind screen described in reference 1. The residual windage tare was approximately 0.3 pound at a speed of 82.0 feet per second. The proper tares were deducted from the measured drags to obtain the hydrodynamic resistances. The tares for load and moment were negligible.

The quantities measured are generally believed to be accurate within the following limits:

Load, lb	± 0.15
Resistance, lb	± 0.15
Trimming moment, ft-lb	± 0.50
Wetted length, in.	± 0.25
Trim, deg	± 0.10
Speed, fps	± 0.20

RESULTS AND DISCUSSION

The experimental data are presented for the angles of dead rise of 20° and 40° in tables I and II, respectively. In these tables, the load, resistance, speed, wetted lengths, and center-of-pressure location are given as nondimensional coefficients based on the over-all beam. The lift and drag coefficients are expressed both in terms of the square of this beam and in terms of the principal wetted area. As reported in references 1 and 4, some of the light-load, low-speed conditions of the test program were influenced by buoyancy. For the 20° dead-rise surface, these conditions were deleted on the basis of the supplementary low-speed program described in reference 1 by using figure 18 of reference 1 as the limit for planing. For the 40° surface, all conditions were deleted where buoyancy exceeded 20 percent of the total load as discussed in reference 4.

The data in tables I and II are presented in figures 5 to 14. The results of this investigation parallel those of the investigations reported in references 1 to 4 in that the principal planing characteristics are primarily functions of lift coefficient and trim. (See figs. 5, 6, 9, 10, 13, and 14.)

The friction coefficients presented in figures 15 and 16 were calculated directly from the tabular data. All conditions where the possible error in measurement could change the coefficient more than 20 percent were omitted from the plot. The projected wetted area S was used to determine the mean speed over the surface. The actual wetted area S_f, including the inside faces and edges of the chine strips, was used to calculate the friction coefficients.

In general, the variation of wetted length, center-of-pressure location, and resistance follows the trends previously established in references 1 to 4. The effect of change in dead rise on these planing characteristics is similar to that found previously for the V-shaped surfaces with horizontal chine flare and without chine flare (refs. 1 to 4). As for the other surfaces, the apparent values of the friction coefficients at the higher Reynolds numbers lie above the Schoenherr line for flat submerged surfaces with fully turbulent boundary layers. As the models were extremely smooth, this result is apparently associated with the method of calculation and requires further investigation for a more accurate estimation of large-scale resistance.

Comparisons of the planing characteristics of the surfaces reported in references 1 to 4 and those of the present paper are presented in figures 17 to 20. These comparisons are made at mean-wetted-length—beam ratios of 1.0 and 3.0. The effect of increase in angle of dead rise on the variation of lift coefficient with trim is presented in figure 17. Increasing the angle of dead rise from 0° to 20° resulted in a loss in lift of approximately 27 percent, the actual loss varying slightly with wetted area and trim. In like manner for the 40° dead-rise surface, the decrease in lift was approximately 50 percent.

Much of the loss in lift with increase in angle of dead rise was recovered by use of either horizontal chine flare or vertical chine strips. (See figs. 17 and 18.) The vertical strips were the more effective of the two; the lift of the 20° surface with vertical chine strips actually approaches that of the flat plate. The lifts of the various surfaces are briefly compared with those of the flat plate in the following table.

Surface	Percent of the lift in relation to flat plate for mean wetted lengths of -	
	1.0	3.0
Flat plate	100	100
20° dead rise, vertical strips	90	92
20° dead rise, horizontal flare	85	82
40° dead rise, vertical strips	80	77
20° dead rise	73	73
40° dead rise, horizontal flare	70	68
40° dead rise	50	45

The relative order of the lifting efficiencies of the various surfaces may be obtained from a comparison of the measured lift-drag ratios presented in figures 19 and 20. Increasing the angle of dead rise decreases lift-drag ratios at all trims. The angle at which maximum lift-drag ratio occurs is also shifted to higher trims. At the higher trims where the frictional resistance becomes a smaller part of the total resistance, the differences in lift-drag ratio become small and the ratio approaches a value equal to the cotangent of the trim angle. At these high trims the drag is principally induced drag which is equal to the load times the tangent of the trim angle. The ratios for the flat plate at high trims actually exceed cotangent τ, presumably because of apparent negative friction due to reversed flow forward of the stagnation line as discussed in reference 2.

The modification of the V-shaped surfaces with horizontal chine flare or vertical chine strips substantially increased the maximum lift-drag ratios of these surfaces. (See fig. 20.) Although the addition of vertical chine strips caused a greater increase in lift than did horizontal chine flare, the additional friction associated with the vertical strips apparently compensated for the increase in lift, and the maximum lift-drag ratios of the models with vertical strips were comparable to those of the models having horizontal chine flare. At higher trims where the friction forces are small the lift-drag ratios again approach a value equal to the cotangent of the trim angle.

Since the deduced friction coefficients at high Reynolds number for all the surfaces are generally parallel to the Schoenherr line, the same trends would be expected at larger scales although the absolute values of lift-drag ratios where friction is appreciable will, of course, be somewhat higher.

CONCLUDING REMARKS

The results obtained from an experimental investigation of two planing surfaces having angles of dead rise of 20° and 40° with vertical chine strips show that the important planing characteristics are primarily functions of trim and lift coefficient. These results are consistent with those obtained with related surfaces having angles of dead rise of 0°, 20°, and 40°, and for surfaces having angles of dead rise of 20° and 40° with horizontally flared chines.

Comparisons of the planing characteristics of these related surfaces show that the flat plate develops approximately 37 percent and 100 percent more lift than do the surfaces having dead-rise angles of 20° and 40°, respectively. Furthermore, the addition of vertical chine strips increases the lift of a V-shaped surface considerably more than does horizontal chine flare. Investigation of lift-drag ratios, however, shows that this increase in lift by use of vertical chine strips is largely compensated for by an accompanying increase in drag so that the lifting efficiencies of horizontally flared surfaces are comparable to those having vertical chine flare.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 16, 1953.

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TABLE I

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 20° ANGLE OF DEAD RISE AND VERTICAL CHINE STRIPS - LANGLEY TANK MODEL 276B

[Average kinematic viscosity = 12.10×10^{-6} ft^2/sec; specific weight of tank water = 63.4 lb/cu ft]

Trim, τ, deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_S}	C_{D_S}
2	0.78	6.07	0.36	1.99	3.28	4.58	1.80	0.0424	0.0194	0.013	0.0059
2	5.84	16.58	2.12	2.02	3.31	4.61	2.30	.0424	.0154	.013	.0047
2	5.84	16.58	2.16	2.02	3.31	4.61	2.36	.0424	.0158	.013	.0048
2	5.84	16.65	2.15	1.99	3.34	4.70	2.50	.0422	.0156	.013	.0047
2	5.84	16.74	2.04	2.06	3.39	4.73	2.18	.0416	.0146	.012	.0043
2	5.84	18.02	1.89	1.07	2.37	3.66	1.54	.0360	.0116	.015	.0049
2	5.84	18.03	1.98	1.07	2.37	3.66	1.63	.0360	.0122	.015	.0051
2	5.84	19.52	1.81	.56	1.86	3.15	1.25	.0306	.0094	.016	.0051
2	5.84	19.62	1.75	.48	1.82	3.15	1.05	.0304	.0092	.017	.0051
2	5.84	19.68	1.77	.37	1.65	2.93	1.22	.0302	.0092	.018	.0056
2	5.84	22.74	2.08	0	1.28	2.55	1.16	.0226	.0080	.018	.0062
2	9.72	18.08	4.02	4.94	6.32	7.71	4.19	.0594	.0246	.009	.0039
2	9.72	18.14	4.38	4.80	6.09	7.39	4.51	.0590	.0266	.010	.0044
2	9.72	18.17	4.04	4.93	6.22	7.52	4.30	.0588	.0244	.009	.0039
2	9.72	21.34	3.34	1.99	3.30	4.61	2.21	.0426	.0146	.013	.0044
2	9.72	21.39	3.62	2.02	3.31	4.61	2.56	.0424	.0158	.013	.0048
2	9.72	21.42	3.32	2.08	3.41	4.75	2.24	.0424	.0144	.012	.0042
2	9.72	24.63	2.89	.70	2.00	3.30	1.13	.0320	.0096	.016	.0048
2	9.72	24.63	3.09	.73	2.03	3.32	1.25	.0320	.0102	.016	.0050
2	9.72	24.78	3.04	1.21	2.31	3.39	1.05	.0316	.0100	.014	.0043
2	9.72	24.75	2.89	.56	1.83	3.10	.87	.0318	.0094	.017	.0051
2	17.50	23.32	7.19	5.33	6.67	8.00	5.03	.0644	.0264	.010	.0040
2	17.50	24.63	7.13	5.41	6.54	7.66	4.42	.0576	.0236	.009	.0036
2	17.50	24.63	7.08	5.26	6.46	7.66	4.36	.0576	.0234	.009	.0036
2	17.50	24.75	6.80	4.36	5.70	7.03	3.98	.0572	.0222	.010	.0039
4	.78	6.07	.19	.05	.66	1.26	.41	.0424	.0104	.064	.0158
4	1.94	7.12	.36	1.31	1.90	2.50	1.19	.0766	.0144	.040	.0076
4	1.94	7.12	.36	1.21	1.82	2.42	1.16	.0766	.0140	.042	.0077
4	1.94	10.45	.37	.12	.73	1.34	.99	.0356	.0068	.049	.0093
4	3.89	8.12	.80	3.80	4.44	5.09	2.62	.1180	.0244	.027	.0055
4	3.89	10.13	.70	1.02	1.66	2.31	1.25	.0758	.0136	.046	.0082
4	3.89	13.51	.66	.24	.85	1.45	.64	.0426	.0072	.050	.0085
4	5.84	9.98	1.29	3.90	4.50	5.09	2.91	.1172	.0258	.026	.0057
4	5.84	12.56	1.04	1.16	1.76	2.38	1.25	.0740	.0132	.042	.0075
4	5.84	16.74	1.03	.24	.82	1.41	.61	.0416	.0074	.051	.0090
4	9.72	10.73	2.27	7.52	8.13	8.73	5.55	.1688	.0394	.021	.0048
4	9.72	16.16	1.70	1.34	1.98	2.62	1.34	.0744	.0130	.038	.0066
4	9.72	18.17	1.63	.66	1.25	1.84	.81	.0588	.0098	.047	.0078
4	9.72	21.24	1.62	.21	.81	1.41	.61	.0430	.0072	.053	.0089
4	17.50	17.37	3.73	3.88	4.55	5.22	3.23	.1160	.0248	.025	.0054
4	17.50	21.51	3.27	1.45	2.06	2.67	1.28	.0756	.0142	.037	.0069
4	17.50	24.63	2.99	.37	1.07	1.76	.73	.0576	.0098	.054	.0092
4	25.28	20.70	5.37	3.96	4.62	5.28	3.32	.1180	.0250	.025	.0054
4	25.28	24.78	4.81	1.82	2.42	3.02	1.72	.0824	.0156	.034	.0064
4	33.06	19.68	7.62	7.39	8.00	8.61	---	.1708	.0394	.021	.0049
4	33.06	23.52	7.01	4.85	5.22	5.58	3.32	.1196	.0254	.023	.0049
4	33.06	24.78	6.87	3.10	3.69	4.29	2.88	.1076	.0224	.029	.0061
6	.78	4.51	.14	.50	.89	1.28	.06	.0766	.0134	.086	.0151
6	1.94	7.27	.39	.31	.75	1.21	.81	.0734	.0148	.098	.0197
6	5.84	9.85	.97	1.26	1.71	2.15	1.16	.1204	.0200	.070	.0117
6	5.84	9.91	1.02	1.34	1.74	2.15	1.28	.1190	.0208	.068	.0120
6	5.84	12.53	.91	.39	.78	1.16	.49	.0744	.0116	.095	.0149
6	9.72	9.32	1.94	5.26	5.66	6.06	3.78	.2238	.0448	.039	.0079
6	9.72	10.52	1.81	3.20	3.61	4.02	2.56	.1756	.0326	.049	.0090
6	9.72	15.92	1.60	.37	.80	1.21	.58	.0768	.0126	.096	.0158
6	9.72	16.02	1.58	.48	.87	1.26	.55	.0758	.0124	.087	.0143
6	17.50	12.16	3.44	5.21	5.64	6.06	3.93	.2366	.0466	.042	.0083
6	17.50	17.42	2.92	1.28	1.67	2.06	1.10	.1154	.0192	.069	.0115
6	17.50	21.63	2.85	.44	.82	1.21	.52	.0748	.0122	.091	.0149
6	17.50	24.78	2.85	.21	.62	1.02	.44	.0570	.0092	.092	.0148
6	25.28	14.87	5.08	5.34	5.74	6.13	3.98	.2286	.0460	.040	.0080
6	25.28	17.48	4.60	2.91	3.37	3.83	2.38	.1654	.0302	.049	.0090
6	25.28	21.03	4.18	1.02	1.50	1.99	1.13	.1144	.0190	.076	.0127
6	25.28	24.75	4.11	.44	.82	1.21	.58	.0826	.0134	.101	.0163
6	33.06	14.87	6.76	7.56	7.99	8.42	---	.2990	.0612	.037	.0077
6	33.06	17.03	6.66	5.12	5.50	5.87	3.91	.2280	.0460	.041	.0084
6	33.06	19.92	6.03	2.99	3.41	3.83	2.38	.1666	.0304	.049	.0089
6	33.06	20.28	5.88	2.55	2.97	3.39	2.21	.1608	.0286	.054	.0096
6	33.06	23.86	5.50	1.12	1.57	2.02	1.19	.1162	.0194	.074	.0124
6	33.06	24.78	5.36	1.05	1.44	1.84	.78	.1076	.0174	.075	.0121
6	48.62	18.02	9.81	7.32	7.74	8.14	---	.2994	.0604	.039	.0078
6	48.62	20.28	9.47	5.09	5.51	5.93	3.94	.2364	.0460	.043	.0083

TABLE I - Continued

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 20° ANGLE OF DEAD RISE AND VERTICAL CHINE STRIPS - LANGLEY TANK MODEL 276B

Trim, τ, deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_S}	C_{D_S}
6	48.62	24.33	8.83	2.76	3.17	3.57	2.20	0.1642	0.0298	0.052	0.0094
6	64.18	20.58	13.04	7.03	7.45	7.85	---	.3030	.0616	.041	.0083
6	64.18	22.54	12.79	5.74	6.08	6.42	---	.2526	.0504	.041	.0083
6	64.18	23.83	12.61	4.75	5.14	5.53	---	.2260	.0444	.044	.0086
12	.78	4.57	.16	.19	.38	.58	---	.0748	.0158	.197	.0416
12	1.94	4.81	.41	.73	.87	1.02	.58	.1676	.0356	.193	.0409
12	1.94	7.15	.42	.12	.19	.38	.32	.0758	.0164	.399	.0863
12	5.84	10.07	1.33	.37	.56	.75	.32	.1152	.0262	.206	.0468
12	5.84	12.25	1.33	.08	.29	.51	---	.0778	.0178	.268	.0614
12	5.84	12.53	1.28	.19	.38	.58	.26	.0744	.0162	.196	.0426
12	9.72	9.25	2.25	1.09	1.28	1.47	.84	.2272	.0524	.177	.0409
12	9.72	10.73	2.24	.37	.67	.97	.61	.1688	.0388	.252	.0579
12	9.72	16.13	2.20	.08	.25	.44	.26	.0748	.0170	.299	.0680
12	17.50	8.71	4.26	4.07	4.26	4.45	2.76	.4614	.1124	.108	.0264
12	17.50	9.52	4.21	2.83	2.99	3.15	2.06	.3862	.0928	.129	.0310
12	17.50	9.61	4.18	2.72	2.89	3.05	1.92	.3790	.0906	.131	.0313
12	17.50	12.31	4.04	1.16	1.34	1.50	1.16	.2310	.0534	.172	.0398
12	17.50	12.31	4.08	1.07	1.26	1.45	.84	.2310	.0538	.183	.0427
12	17.50	12.35	4.12	1.05	1.20	1.36	.92	.2294	.0540	.191	.0450
12	17.50	16.21	3.90	.34	.53	.73	---	.1332	.0296	.251	.0558
12	17.50	17.19	4.00	.31	.46	.63	.29	.1184	.0270	.257	.0587
12	17.50	21.63	4.02	.19	.38	.58	.29	.0748	.0172	.197	.0453
12	25.28	14.78	5.92	1.07	1.22	1.38	.84	.2314	.0542	.031	.0444
12	25.28	17.42	5.90	.58	.76	.92	.49	.1666	.0388	.219	.0511
12	25.28	20.72	5.80	.39	.54	.70	.32	.1178	.0270	.218	.0500
12	25.28	24.72	5.92	.08	.28	.48	.29	.0828	.0194	.296	.0693
12	33.06	11.96	8.07	3.93	4.07	4.22	2.76	.4622	.1128	.114	.0277
12	33.06	12.25	7.97	3.46	3.70	3.93	2.37	.4406	.1062	.119	.0287
12	33.06	14.93	7.81	1.74	1.92	2.08	1.37	.2966	.0702	.154	.0366
12	33.06	17.25	7.77	1.02	1.18	1.34	.81	.2222	.0522	.188	.0442
12	33.06	19.68	7.56	.68	.87	1.06	.52	.1708	.0390	.196	.0448
12	33.06	24.09	7.43	.37	.52	.68	.32	.1140	.0256	.219	.0492
12	48.62	14.42	11.92	3.83	4.01	4.19	2.88	.4676	.1146	.117	.0286
12	48.62	16.16	11.64	2.64	2.82	3.01	1.98	.3724	.0892	.132	.0316
12	48.62	20.66	11.53	1.05	1.24	1.44	.90	.2278	.0540	.184	.0435
12	48.62	24.12	11.25	.56	.74	.92	.61	.1672	.0386	.226	.0522
12	64.18	20.72	15.15	1.74	1.93	2.11	1.40	.2990	.0706	.155	.0366
12	64.18	24.03	15.02	.95	1.14	1.34	.81	.2222	.0520	.195	.0456
12	79.74	18.23	19.56	4.32	4.51	4.70	2.79	.4798	.1176	.106	.0261
12	79.74	18.32	19.67	3.76	3.94	4.12	2.73	.4752	.1172	.121	.0297
12	79.74	20.49	19.10	2.73	2.95	3.15	2.01	.3798	.0910	.129	.0308
12	79.74	24.63	18.47	1.31	1.50	1.70	1.16	.2628	.0608	.175	.0405
12	79.74	24.75	18.55	1.26	1.50	1.74	1.10	.2604	.0606	.174	.0404
18	.78	3.09	.28	.29	.41	.53	---	.1634	.0592	.398	.1444
18	.78	3.63	.29	.17	.29	.41	.20	.1184	.0444	.408	.1531
18	.78	4.51	.29	.08	.19	.31	---	.0766	.0288	.403	.1516
18	1.94	3.18	.59	1.21	1.33	1.45	.78	.3838	.1174	.289	.0883
18	1.94	3.21	.63	1.24	1.35	1.45	.84	.3766	.1224	.279	.0907
18	1.94	4.15	.66	.50	.63	.76	.34	.2254	.0764	.358	.1213
18	1.94	4.81	.62	.34	.46	.58	.27	.1676	.0536	.364	.1165
18	5.84	5.56	1.97	1.18	1.31	1.44	1.03	.3778	.1276	.288	.0974
18	5.84	7.12	1.98	.53	.66	.80	.52	.2304	.0782	.349	.1185
18	5.84	9.91	1.91	.08	.23	.39	.15	.1190	.0388	.517	.1687
18	9.72	9.25	3.21	.44	.56	.70	.38	.2272	.0752	.406	.1343
18	9.72	10.76	3.20	.24	.39	.53	.27	.1680	.0554	.431	.1421
18	17.50	8.71	5.89	1.70	1.82	1.94	1.22	.4614	.1552	.253	.0853
18	17.50	8.71	5.92	1.65	1.76	1.89	1.26	.4614	.1562	.262	.0888
18	17.50	9.52	5.93	1.26	1.37	1.47	.98	.3862	.1310	.282	.0956
18	17.50	9.58	5.87	1.18	1.32	1.45	1.05	.3814	.1280	.289	.0970
18	17.50	12.25	5.82	.50	.65	.80	.36	.2332	.0776	.359	.1194
18	17.50	17.42	5.99	.10	.24	.39	.25	.1154	.0394	.481	.1642
18	25.28	14.69	8.41	.46	.58	.70	.53	.2342	.0780	.404	.1345
18	25.28	17.25	8.44	.29	.44	.58	.39	.1700	.0568	.386	.1291
18	25.28	20.85	8.36	.14	.31	.48	.29	.1164	.0384	.375	.1239
18	33.06	11.74	11.17	1.74	1.85	1.96	1.35	.4798	.1620	.259	.0876
18	33.06	14.84	11.01	.82	.93	1.05	.72	.3002	.1000	.323	.1075
18	33.06	19.56	10.96	.27	.42	.55	.36	.1728	.0572	.411	.1362
18	33.06	24.78	11.10	.12	.26	.41	.22	.1076	.0362	.414	.1392
18	48.62	14.51	16.23	1.65	1.78	1.92	1.22	.4618	.1542	.259	.0866
18	48.62	16.10	16.23	1.18	1.32	1.45	.91	.3752	.1252	.284	.0948
18	48.62	20.69	16.10	.46	.61	.76	.43	.2272	.0752	.372	.1233
18	48.62	20.72	15.98	.44	.58	.73	.40	.2264	.0744	.390	.1283

TABLE I - Continued

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 20° ANGLE OF DEAD RISE AND VERTICAL CHINE STRIPS - LANGLEY TANK MODEL 276B

Trim, τ, deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_S}	C_{D_S}
18	48.62	24.09	16.29	0.21	0.37	0.53	0.24	0.1676	0.0562	0.453	0.1519
18	48.62	24.15	16.45	.29	.43	.56	.30	.1668	.0564	.388	.1312
18	64.18	16.62	21.37	1.65	1.76	1.89	1.22	.4648	.1548	.264	.0880
18	64.18	20.79	21.25	.85	.95	1.05	.61	.2970	.0984	.313	.1036
18	64.18	23.83	21.27	.48	.59	.70	.40	.2260	.0750	.383	.1271
18	79.74	18.42	26.94	1.63	1.76	1.89	1.25	.4700	.1588	.267	.0902
18	79.74	20.66	26.56	1.18	1.32	1.45	.89	.3736	.1244	.283	.0942
18	79.74	23.10	26.68	.73	.85	.99	.62	.2988	.1000	.351	.1176
18	79.74	24.49	26.51	.60	.75	.89	.52	.2660	.0884	.355	.1179
24	.78	3.06	.28	.21	.30	.38	---	.1666	.0604	.555	.2013
24	.78	3.69	.32	.10	.19	.27	---	.1146	.0470	.603	.2474
24	.78	4.53	.33	.02	.11	.19	---	.0760	.0320	.696	.2909
24	1.94	2.92	.80	1.09	1.18	1.28	.84	.4548	.1882	.385	.1595
24	1.94	3.27	.71	.76	.85	.95	---	.3630	.1332	.427	.1567
24	1.94	3.27	.82	.80	.88	.97	.67	.3630	.1538	.412	.1748
24	1.94	4.12	.73	.27	.39	.50	---	.2286	.0860	.586	.2205
24	1.94	4.15	.82	.39	.48	.58	---	.2254	.0954	.470	.1988
24	1.94	4.84	.72	.19	.31	.44	---	.1656	.0616	.534	.1987
24	1.94	4.84	.83	.19	.30	.41	---	.1656	.0710	.552	.2367
24	5.84	5.64	2.47	.78	.87	.95	.67	.3672	.1556	.422	.1788
24	5.84	7.06	2.52	.37	.45	.53	.35	.2344	.1012	.521	.2249
24	9.72	7.21	4.36	.76	.85	.95	.49	.3740	.1680	.440	.1976
24	9.72	9.10	4.21	.37	.48	.58	.35	.2348	.1016	.489	.2117
24	9.72	10.67	4.24	.14	.27	.41	.20	.1708	.0744	.633	.2756
24	17.50	8.56	7.76	1.16	1.26	1.36	.76	.4776	.2118	.379	.1681
24	17.50	9.55	7.78	.82	.89	.97	.52	.3838	.1706	.431	.1917
24	17.50	12.25	7.73	.37	.46	.56	.26	.2332	.1030	.507	.2239
24	17.50	17.34	7.66	.10	.21	.34	.09	.1164	.0510	.554	.2429
24	17.50	21.54	7.65	.05	.16	.27	.09	.0754	.0330	.471	.2062
24	25.28	11.56	11.29	.80	.88	.97	.58	.3784	.1690	.430	.1920
24	25.28	13.04	11.20	.58	.68	.78	.44	.2974	.1318	.437	.1938
24	25.28	14.81	11.13	.39	.48	.56	.32	.2306	.1014	.480	.2112
24	25.28	17.40	11.07	.14	.27	.41	.20	.1670	.0732	.618	.2711
24	25.28	20.72	10.93	.10	.21	.34	.12	.1178	.0510	.561	.2429
24	33.06	11.93	14.72	1.05	1.18	1.31	.78	.4646	.2068	.393	.1753
24	33.06	14.96	14.61	.56	.67	.78	.44	.2954	.1306	.441	.1949
24	33.06	19.46	14.48	.24	.33	.41	.23	.1746	.0764	.529	.2315
24	33.06	24.63	14.35	.12	.24	.37	.14	.1090	.0474	.454	.1975
24	48.62	14.33	21.63	1.02	1.12	1.21	.84	.4736	.2106	.423	.1880
24	48.62	16.02	21.67	.80	.89	.99	.64	.3798	.1690	.426	.1899
24	48.62	20.64	21.52	.39	.48	.56	---	.2292	.1010	.475	.2104
24	48.62	24.33	21.63	.21	.30	.38	.14	.1642	.0730	.547	.2433
24	64.18	16.74	28.80	1.09	1.18	1.26	.76	.4580	.2056	.388	.1742
24	64.18	18.42	28.87	.85	.93	1.02	.55	.3784	.1702	.407	.1830
24	64.18	20.72	28.91	.58	.67	.76	.38	.2990	.1348	.446	.2012
24	64.18	20.79	28.50	.56	.66	.76	.35	.2970	.1318	.450	.1997
24	64.18	24.37	28.29	.34	.46	.58	---	.2162	.0952	.470	.2070
24	64.18	24.94	28.17	.34	.45	.56	---	.2064	.0906	.459	.2013
24	79.74	18.54	36.00	1.09	1.20	1.31	.76	.4640	.2094	.387	.1745
24	79.74	20.43	35.94	.85	.93	1.02	.61	.3820	.1722	.411	.1852
24	79.74	23.14	36.13	.56	.64	.73	.46	.2978	.1350	.465	.2109
24	79.74	24.84	36.05	.46	.55	.63	.39	.2584	.1168	.470	.2124
30	.78	4.50	.44	.05	.12	.17	---	.0738	.0414	.615	.3450
30	1.94	4.15	1.10	.37	.43	.48	.18	.2254	.1272	.524	.2958
30	1.94	4.75	1.10	.24	.31	.37	.23	.1720	.0972	.555	.3135
30	3.89	6.91	2.29	.21	.27	.34	.16	.1630	.0960	.604	.3556
30	5.84	7.12	3.40	.39	.44	.48	.09	.2304	.1344	.524	.3055
30	5.84	10.12	3.33	.12	.17	.24	---	.1140	.0650	.671	.3824
30	9.72	7.21	5.51	.78	.82	.87	.39	.3740	.2156	.456	.2629
30	9.72	9.22	5.60	.31	.37	.44	.18	.2286	.1316	.618	.3557
30	9.72	10.78	5.54	.21	.29	.37	.08	.1672	.0954	.577	.3290
30	9.72	17.31	5.28	.05	.12	.19	.01	.0648	.0352	.540	.2933
30	17.50	8.65	10.23	.89	.97	1.05	.55	.4678	.2734	.482	.2819
30	17.50	9.64	10.10	.70	.76	.82	.41	.3766	.2174	.495	.2861
30	17.50	12.62	10.04	.37	.43	.48	.17	.2198	.1262	.511	.2935
30	17.50	17.54	9.91	.08	.16	.24	.11	.1138	.0644	.711	.4025
30	17.50	21.54	9.81	.10	.17	.24	.06	.0754	.0422	.314	.1758
30	25.28	10.36	14.61	1.02	1.07	1.11	.61	.4710	.2722	.440	.2544
30	25.28	14.93	14.45	.34	.41	.48	.16	.2268	.1296	.553	.3161
30	25.28	15.02	14.45	.39	.45	.50	.19	.2242	.1222	.499	.2849
30	25.28	17.42	14.36	.19	.23	.37	.21	.1666	.0946	.595	.3379
30	25.28	20.69	14.24	.10	.17	.24	.14	.1182	.0566	.695	.3918

TABLE I - Concluded

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 20° ANGLE OF DEAD RISE

AND VERTICAL CHINE STRIPS - LANGLEY TANK MODEL 276B

Trim, τ, deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_S}	C_{D_S}
30	25.28	20.79	14.63	0.08	0.16	0.24	0.11	0.1170	0.0676	0.731	0.4225
30	33.06	11.93	19.03	.87	.93	.99	.58	.4646	.2674	.500	.2875
30	33.06	14.87	18.93	.48	.54	.68	.29	.2990	.1712	.554	.3170
30	33.06	15.02	18.79	.50	.56	.63	.34	.2930	.1666	.523	.2975
30	33.06	18.26	18.60	.27	.34	.41	.18	.1984	.1116	.583	.3282
30	33.06	19.74	18.52	.21	.29	.37	.16	.1696	.0950	.585	.3276
30	33.06	19.82	18.62	.24	.31	.37	.14	.1684	.0948	.543	.3058
30	33.06	19.89	18.67	.24	.31	.39	.12	.1672	.0944	.539	.3045
30	33.06	23.40	18.79	.24	.31	.37	.12	.1208	.0686	.390	.2213
30	33.06	23.83	17.45	.12	.21	.31	---	.1164	.0614	.554	.2924
30	33.06	24.84	18.01	.10	.17	.24	.03	.1072	.0584	.631	.3435
30	48.62	14.60	28.29	.87	.93	.99	.57	.4562	.2654	.490	.2854
30	48.62	15.86	28.16	.70	.78	.85	.39	.3866	.2238	.496	.2869
30	48.62	19.74	28.11	.44	.50	.56	.27	.2496	.1442	.499	.2884
30	48.62	20.82	27.59	.34	.41	.48	.19	.2244	.1274	.547	.3107
30	48.62	23.74	27.84	.24	.31	.37	.12	.1726	.0988	.557	.3187
30	48.62	24.18	27.77	.24	.31	.37	.16	.1664	.0950	.537	.3065
30	64.18	16.68	37.38	.97	1.03	1.09	.64	.4614	.2686	.448	.2608
30	64.18	20.88	36.99	.50	.56	.63	.35	.2944	.1698	.526	.3032
30	64.18	24.43	37.00	.34	.41	.46	.23	.2150	.1240	.524	.3024
30	79.74	18.52	46.43	.97	1.02	1.07	---	.4650	.2708	.456	.2655
30	79.74	20.66	46.14	---	---	---	---	.3736	.2162	---	---
30	79.74	24.77	46.08	.44	.50	.56	---	.2600	.1502	.520	.3004

TABLE II

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 40° ANGLE OF DEAD RISE AND VERTICAL CHINE STRIPS - LANGLEY TANK MODEL 277B

[Average kinematic viscosity = 13.50×10^{-6} ft²/sec; specific weight of tank water = 63.4 lb/cu ft]

Trim, τ, deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_S}	C_{D_S}
4	1.94	9.47	0.68	0.31	1.73	3.15	1.22	0.0432	0.0152	0.025	0.0088
4	1.94	9.55	.65	.34	1.79	3.25	1.19	.0426	.0142	.024	.0079
4	3.89	10.21	1.22	1.77	3.18	4.58	1.93	.0746	.0234	.023	.0074
4	5.84	12.71	1.76	1.70	3.18	4.65	1.93	.0724	.0218	.023	.0068
4	9.72	12.80	3.16	4.61	6.18	7.74	3.82	.1186	.0386	.019	.0062
4	9.72	13.52	3.15	4.27	5.78	7.27	3.47	.1064	.0344	.018	.0060
4	9.72	13.52	3.19	4.19	5.72	7.22	3.43	.1064	.0348	.019	.0061
4	9.72	15.99	3.02	1.84	3.36	4.90	1.98	.0760	.0236	.023	.0070
4	9.72	16.16	2.94	1.65	3.10	4.56	1.90	.0744	.0224	.024	.0072
4	9.72	18.32	2.90	.78	2.33	3.88	1.23	.0580	.0172	.025	.0074
4	9.72	18.33	2.88	.92	2.40	3.88	1.25	.0578	.0172	.024	.0072
4	9.72	21.34	3.06	.41	1.92	3.42	.99	.0426	.0134	.022	.0070
4	9.72	21.48	3.14	.58	1.93	3.28	.97	.0422	.0136	.022	.0070
4	17.50	17.37	5.51	4.85	6.31	7.76	4.01	.1160	.0366	.018	.0058
4	17.50	21.34	5.19	1.70	3.23	4.75	2.00	.0768	.0228	.024	.0070
4	17.50	24.58	5.22	.73	2.24	3.76	1.22	.0580	.0172	.026	.0077
4	25.28	20.79	7.75	4.61	6.19	7.76	4.00	.1170	.0358	.019	.0058
4	25.28	24.78	7.52	2.11	3.74	5.36	2.30	.0824	.0244	.022	.0065
4	33.06	24.03	10.05	4.67	6.14	7.58	3.90	.1144	.0348	.019	.0057
4	33.06	24.63	9.87	4.00	5.46	6.90	3.69	.1090	.0326	.020	.0060
6	1.94	7.21	.55	.56	1.52	2.47	.98	.0746	.0212	.049	.0139
6	3.89	6.82	.95	3.05	4.01	4.96	2.49	.1672	.0408	.042	.0102
6	3.89	8.18	.96	1.76	2.68	3.61	1.54	.1162	.0286	.043	.0107
6	3.89	10.21	.89	.53	1.50	2.47	.79	.0746	.0170	.050	.0113
6	5.84	10.01	1.41	1.45	2.39	3.34	1.71	.1166	.0282	.049	.0180
6	5.84	10.01	1.39	1.45	2.42	3.39	1.65	.1166	.0278	.048	.0115
6	5.84	10.07	1.40	1.45	2.36	3.27	1.72	.1152	.0276	.049	.0117
6	9.72	10.67	2.33	3.35	4.26	5.16	2.67	.1708	.0410	.040	.0096
6	9.72	10.73	2.38	3.50	4.50	5.50	2.92	.1688	.0414	.037	.0092
6	9.72	10.73	2.36	3.41	4.49	5.55	2.92	.1688	.0410	.038	.0091
6	9.72	16.13	2.19	.77	1.60	2.42	.83	.0748	.0168	.047	.0105
6	9.72	16.16	2.20	.60	1.52	2.42	.81	.0744	.0168	.049	.0110
6	17.50	12.16	4.37	5.93	6.86	7.76	4.25	.2366	.0592	.034	.0086
6	17.50	12.25	4.31	6.25	7.20	8.15	4.03	.2332	.0574	.032	.0080
6	17.50	12.35	4.42	6.35	7.31	8.26	4.54	.2294	.0580	.031	.0079
6	17.50	14.54	4.20	3.28	4.23	5.18	2.82	.1656	.0398	.039	.0093
6	17.50	17.34	3.91	1.55	2.48	3.39	1.54	.1164	.0260	.047	.0105
6	17.50	21.60	3.86	.53	1.53	2.54	.77	.0750	.0166	.049	.0108
6	17.50	24.72	4.18	.14	1.17	2.18	.66	.0572	.0136	.049	.0116
6	17.50	24.78	4.23	.24	1.19	2.14	.68	.0570	.0138	.048	.0116
6	25.28	17.42	6.12	3.52	4.47	5.41	2.93	.1666	.0404	.037	.0090
6	25.28	20.94	5.72	1.47	2.43	3.39	1.54	.1152	.0260	.047	.0107
6	25.28	24.75	5.63	.58	1.53	2.48	.84	.0826	.0184	.054	.0120
6	33.06	17.16	8.08	5.62	6.58	7.52	4.25	.2246	.0548	.034	.0083
6	33.06	19.89	7.82	3.41	4.38	5.33	2.93	.1672	.0396	.038	.0090
6	33.06	24.03	7.29	1.53	2.49	3.44	1.54	.1144	.0252	.046	.0101
6	33.06	24.72	7.29	1.21	2.14	3.06	1.33	.1082	.0238	.051	.0111
6	48.62	20.67	11.63	5.70	6.59	7.52	4.27	.2276	.0544	.034	.0082
6	48.62	23.89	11.80	3.39	4.37	5.34	3.04	.1704	.0414	.039	.0095
12	1.94	4.12	.53	1.14	1.62	2.09	1.09	.2286	.0624	.141	.0385
12	1.94	4.15	.48	1.12	1.60	2.07	1.20	.2252	.0558	.141	.0349
12	1.94	4.21	.50	1.05	1.53	2.00	1.08	.2190	.0564	.143	.0369
12	1.94	4.75	.50	.60	1.08	1.55	.79	.1720	.0444	.159	.0411
12	1.94	4.81	.48	.56	1.04	1.51	.83	.1676	.0414	.161	.0398
12	1.94	4.81	.50	.58	1.06	1.53	.71	.1676	.0432	.109	.0282
12	5.84	5.61	1.46	2.70	3.18	3.65	2.00	.3712	.0928	.117	.0292
12	5.84	5.61	1.52	2.72	3.20	3.67	1.97	.3712	.0966	.116	.0302
12	5.84	7.06	1.46	1.14	1.61	2.08	1.21	.2344	.0586	.146	.0364
12	5.84	9.98	1.44	.21	.69	1.16	.38	.1172	.0288	.170	.0417
12	5.84	10.01	1.51	.21	.69	1.16	.51	.1166	.0302	.169	.0438
12	5.84	10.01	1.53	.21	.69	1.16	.52	.1166	.0306	.169	.0443
12	5.84	10.07	1.50	.12	.67	1.21	.41	.1152	.0296	.172	.0442
12	9.72	7.15	2.49	2.96	3.42	3.88	2.22	.3802	.0974	.111	.0285
12	9.72	9.22	2.44	1.21	1.66	2.11	1.02	.2286	.0574	.138	.0346
12	9.72	10.70	2.47	.58	1.07	1.55	.68	.1698	.0432	.159	.0404
12	9.72	10.82	2.48	.61	1.13	1.65	.77	.1660	.0424	.147	.0375
12	9.72	12.85	2.57	.19	.72	1.24	.56	.1178	.0312	.164	.0433
12	17.50	8.62	4.57	4.25	4.73	5.21	2.98	.4710	.1230	.100	.0260
12	17.50	9.50	4.51	3.03	3.51	4.00	2.21	.3878	.1000	.124	.0320
12	17.50	9.55	4.50	2.99	3.41	3.83	2.15	.3838	.0986	.113	.0289
12	17.50	9.61	4.52	2.91	3.36	3.83	2.27	.3790	.0978	.113	.0291
12	17.50	12.19	4.37	1.24	1.83	2.43	1.15	.2356	.0588	.129	.0321

TABLE II - Continued

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 40° ANGLE OF DEAD RISE AND VERTICAL CHINE STRIPS - LANGLEY TANK MODEL 277B

Trim, τ, deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_S}	C_{D_S}
12	17.50	12.25	4.28	1.00	1.56	2.13	1.35	0.2332	0.0570	0.149	0.0365
12	17.50	12.38	4.52	1.02	1.53	2.04	1.14	.2284	.0590	.149	.0386
12	17.50	16.43	4.47	.25	.76	1.24	.40	.1296	.0332	.170	.0437
12	17.50	17.16	4.55	.27	.73	1.26	.36	.1188	.0308	.163	.0422
12	25.28	12.11	6.51	2.60	3.08	3.57	1.99	.3446	.0888	.112	.0288
12	25.28	14.87	6.51	1.36	1.71	2.16	1.15	.2286	.0588	.134	.0344
12	25.28	17.25	6.35	.58	1.09	1.60	.61	.1700	.0426	.156	.0391
12	25.28	17.34	6.45	.53	1.04	1.55	.71	.1682	.0428	.162	.0412
12	25.28	20.67	6.39	.27	.74	1.21	.35	.1184	.0300	.160	.0405
12	25.28	20.72	---	.27	.74	1.21	---	.1178	---	.159	---
12	25.28	21.03	6.57	.10	.66	1.21	.48	.1144	.0296	.173	.0448
12	33.06	11.81	8.59	4.07	4.56	5.05	3.03	.4740	.1232	.104	.0270
12	33.06	11.93	8.59	4.12	4.63	5.14	2.96	.4646	.1208	.100	.0261
12	33.06	12.25	8.11	3.66	4.14	4.61	2.50	.4406	.1080	.106	.0261
12	33.06	12.25	8.55	3.81	4.30	4.78	2.74	.4406	.1140	.102	.0265
12	33.06	13.16	8.53	2.99	3.45	3.90	2.30	.3818	.0984	.111	.0285
12	33.06	13.16	8.61	3.01	3.48	3.95	2.30	.3818	.0994	.110	.0286
12	33.06	14.81	8.57	2.01	2.46	2.91	1.68	.3014	.0782	.122	.0318
12	33.06	19.77	8.37	.60	1.09	1.55	.71	.1692	.0428	.155	.0393
12	33.06	24.40	8.45	.17	.69	1.21	.47	.1110	.0284	.161	.0412
12	48.62	14.36	12.75	4.27	4.63	5.05	3.03	.4749	.1245	.103	.0267
12	48.62	16.02	12.62	2.86	3.34	3.81	2.31	.3788	.0984	.113	.0295
12	48.62	16.10	12.58	2.96	3.37	3.76	2.29	.3752	.0970	.111	.0288
12	48.62	20.64	12.33	1.21	1.71	2.18	1.14	.2282	.0578	.133	.0338
12	48.62	24.63	12.29	.49	1.05	1.62	.69	.1602	.0404	.153	.0385
12	64.18	16.53	16.84	4.00	4.45	4.90	3.02	.4698	.1232	.106	.0277
12	64.18	16.62	16.86	3.93	4.41	4.88	3.01	.4648	.1220	.105	.0277
12	64.18	20.64	16.36	1.99	2.45	2.91	1.70	.3012	.0768	.123	.0313
12	64.18	23.43	16.45	1.18	1.66	2.13	1.18	.2338	.0600	.141	.0361
12	64.18	23.74	16.39	1.07	1.60	2.13	1.16	.2278	.0582	.142	.0364
12	64.18	24.78	16.52	.90	1.43	1.96	1.01	.2090	.0538	.146	.0376
12	79.74	18.63	20.76	4.02	4.50	4.97	2.96	.4594	.1196	.102	.0266
12	79.74	18.63	20.75	3.90	4.38	4.85	2.95	.4594	.1196	.105	.0273
12	79.74	20.49	20.61	2.91	3.39	3.88	2.29	.3798	.0982	.112	.0290
12	79.74	23.20	20.41	1.94	2.47	2.99	1.69	.2962	.0758	.120	.0307
12	79.74	24.63	20.28	1.50	1.98	2.45	1.43	.2628	.0668	.133	.0337
12	79.74	24.69	20.33	1.50	1.99	2.47	1.41	.2616	.0666	.131	.0335
18	1.94	2.92	.66	1.76	2.04	2.31	1.27	.4548	.1548	.223	.0759
18	1.94	3.21	.69	1.28	1.56	1.83	1.30	.3766	.1340	.241	.0859
18	1.94	4.15	.66	.56	.84	1.11	.54	.2252	.0766	.268	.0912
18	1.94	4.21	.67	.53	.81	1.08	.62	.2190	.0756	.270	.0933
18	1.94	4.21	.67	.58	.84	1.12	.62	.2190	.0756	.261	.0900
18	1.94	4.21	.68	.53	.81	1.08	.69	.2190	.0768	.270	.0948
18	1.94	4.81	.70	.34	.62	.89	.61	.1676	.0604	.270	.0974
18	1.94	4.81	.68	.39	.63	.87	.50	.1676	.0588	.266	.0933
18	1.94	4.81	.65	.34	.62	.89	.46	.1676	.0562	.270	.0906
18	5.84	5.38	2.02	1.44	1.72	1.99	1.08	.4036	.1396	.235	.0812
18	5.84	7.15	1.99	.58	.86	1.13	.65	.2284	.0778	.266	.0905
18	5.84	7.21	2.01	.60	.87	1.14	.72	.2248	.0774	.258	.0890
18	5.84	9.91	2.03	.08	.40	.72	.42	.1190	.0414	.297	.1035
18	9.72	7.21	3.39	1.28	1.56	1.83	1.05	.3740	.1304	.240	.0836
18	9.72	9.01	3.34	.63	.92	1.21	.74	.2394	.0822	.260	.0893
18	9.72	10.82	3.34	.31	.61	.89	.52	.1660	.0570	.272	.0934
18	17.50	8.56	6.15	2.04	2.30	2.54	1.57	.4776	.1678	.208	.0730
18	17.50	8.65	6.09	1.82	2.10	2.37	1.53	.4678	.1628	.223	.0775
18	17.50	9.50	6.20	1.16	1.44	1.70	1.12	.3878	.1374	.269	.0954
18	17.50	9.55	6.15	1.44	1.71	1.99	1.15	.3838	.1348	.224	.0788
18	17.50	10.82	6.06	.89	1.17	1.44	.86	.2990	.1036	.256	.0885
18	17.50	12.25	6.03	.58	.86	1.14	.68	.2332	.0804	.271	.0935
18	17.50	12.25	5.77	.68	.96	1.24	---	.2332	.0770	.243	.0802
18	17.50	12.38	5.95	.56	.87	1.18	.58	.2284	.0777	.262	.0893
18	17.50	17.42	6.14	.12	.43	.73	.31	.1154	.0404	.268	.0940
18	25.28	10.52	8.79	1.76	2.04	2.31	1.49	.4568	.1588	.224	.0778
18	25.28	13.07	8.71	.89	1.17	1.44	.84	.2960	.1020	.253	.0872
18	25.28	14.81	8.73	.58	.84	1.12	.61	.2304	.0796	.274	.0948
18	25.28	17.28	8.87	.34	.62	.89	.47	.1694	.0594	.273	.0958
18	25.28	20.72	8.84	.10	.44	.78	.40	.1178	.0412	.268	.0936
18	33.06	11.87	11.50	2.02	2.30	2.57	1.50	.4692	.1632	.204	.0710
18	33.06	13.28	11.42	1.45	1.72	1.99	1.14	.3748	.1296	.218	.0753
18	33.06	14.81	11.42	.97	1.25	1.53	.90	.3014	.1042	.241	.0834
18	33.06	19.58	11.45	.41	.69	.97	.48	.1708	.0592	.247	.0858
18	33.06	24.06	11.64	.12	.43	.73	.30	.1142	.0403	.266	.0937

TABLE II - Continued

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 40° ANGLE OF DEAD RISE AND VERTICAL CHINE STRIPS - LANGLEY TANK MODEL 277B

Trim, τ, deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_S}	C_{D_S}
18	48.62	14.36	10.53	1.57	1.79	2.02	1.26	0.4716	0.1610	0.212	0.0899
18	48.62	14.36	16.98	1.99	2.22	2.44	1.52	.4716	.1605	.212	.0723
18	48.62	16.02	16.86	1.44	1.71	1.96	1.14	.3798	.1314	.221	.0768
18	48.62	17.82	16.60	.95	1.24	1.53	.81	.3062	.1046	.247	.0843
18	48.62	20.52	16.50	.58	.86	1.13	.57	.2310	.0784	.269	.0912
18	48.62	23.92	16.60	.39	.68	.97	.38	.1700	.0580	.250	.0850
18	64.18	16.53	22.29	1.94	2.20	2.44	1.50	.4698	.1632	.213	.0742
18	64.18	16.62	22.18	1.79	2.07	2.34	1.40	.4648	.1604	.224	.0775
18	64.18	20.73	21.91	.90	1.17	1.45	.80	.2986	.1019	.255	.0871
18	64.18	20.79	22.01	.89	1.17	1.44	.75	.2970	.1019	.254	.0871
18	64.18	23.61	21.72	.68	.93	1.18	.56	.2302	.0779	.247	.0838
18	64.18	24.09	21.65	.53	.81	1.08	.48	.2212	.0746	.273	.0921
18	64.18	24.61	22.13	.58	.85	1.12	.53	.2120	.0731	.249	.0860
18	79.74	18.39	27.67	1.94	2.20	2.44	1.47	.4716	.1636	.214	.0744
18	79.74	20.49	27.47	1.41	1.69	1.94	1.11	.3798	.1310	.226	.0781
18	79.74	20.52	27.54	1.45	1.71	1.96	1.11	.3788	.1310	.221	.0766
18	79.74	22.98	27.58	.89	1.17	1.44	.82	.3020	.1345	.258	.0893
18	79.74	24.58	27.41	.73	1.01	1.28	.68	.2640	.0909	.261	.0900
24	1.94	3.18	.89	.92	1.11	1.29	.78	.3838	.1760	.346	.1586
24	1.94	4.15	.89	.49	.69	.86	.49	.2252	.1034	.326	.1499
24	1.94	4.72	.84	.29	.48	.66	---	.1742	.0754	.363	.1571
24	5.84	5.53	2.61	.94	1.14	1.33	.77	.3820	.1706	.335	.1496
24	5.84	7.09	2.64	.46	.68	.90	.44	.2324	.1050	.343	.1549
24	5.84	10.01	2.69	.07	.33	.58	.32	.1166	.0536	.353	.1624
24	5.84	10.01	2.70	.17	.36	.54	.32	.1166	.0538	.324	.1494
24	5.84	12.53	2.77	0	.19	.37	---	.0744	.0352	.396	.1872
24	5.84	12.56	2.80	0	.18	.37	---	.0740	.0354	.400	.1914
24	9.72	9.32	4.40	.41	.60	.78	.44	.2238	.1012	.373	.1687
24	9.72	10.76	4.44	.24	.47	.70	.30	.1680	.0766	.357	.1630
24	17.50	8.65	7.97	1.40	1.55	1.75	.94	.4678	.2130	.302	.1374
24	17.50	9.58	8.02	.97	1.15	1.33	.72	.3814	.1748	.332	.1520
24	17.50	12.14	7.83	.49	.67	.85	.39	.2374	.1062	.354	.1585
24	17.50	12.25	8.02	---	---	---	---	.2332	.1068	---	---
24	17.50	12.32	8.01	.39	.62	.85	.38	.2306	.1056	.372	.1703
24	17.50	17.28	8.15	.07	.32	.55	.23	.1172	.0546	.366	.1706
24	25.28	10.36	11.20	1.29	1.46	1.65	.97	.4710	.2088	.323	.1430
24	25.28	11.53	11.55	.97	1.15	1.33	.78	.3904	.1738	.331	.1511
24	25.28	14.78	11.47	.44	.66	.87	.43	.2314	.1050	.351	.1591
24	25.28	15.08	11.60	.39	.62	.85	.41	.2224	.1020	.359	.1645
24	25.28	17.48	11.60	.19	.41	.68	.30	.1654	.0760	.403	.1854
24	25.28	20.67	11.31	.05	.33	.61	.23	.1184	.0530	.359	.1606
24	33.06	11.96	14.98	1.29	1.46	1.65	.94	.4622	.2094	.317	.1434
24	33.06	13.07	15.06	.92	1.13	1.33	.74	.3870	.1764	.342	.1561
24	33.06	14.73	14.85	.66	.85	1.04	.54	.3048	.1368	.367	.1648
24	33.06	14.90	15.06	.63	.81	.99	.53	.2978	.1356	.368	.1674
24	33.06	18.03	14.85	.32	.55	.78	.32	.2034	.0914	.370	.1662
24	33.06	19.77	14.95	.19	.41	.68	.31	.1692	.0764	.413	.1863
24	33.06	21.69	15.05	.15	.38	.61	.23	.1406	.0640	.370	.1684
24	33.06	23.89	15.12	.12	.35	.58	.24	.1158	.0530	.331	.1514
24	48.62	14.30	22.20	1.35	1.49	1.64	.99	.4756	.2172	.319	.1458
24	48.62	14.33	21.89	1.33	1.48	1.63	.96	.4736	.2132	.320	.1440
24	48.62	15.99	21.75	.90	1.08	1.26	.70	.3804	.1702	.352	.1576
24	48.62	17.94	21.61	.63	.82	1.01	.55	.3022	.1342	.368	.1636
24	48.62	20.52	21.63	.41	.62	.83	.40	.2310	.1028	.373	.1658
24	48.62	20.54	22.12	.46	.69	.92	.43	.2292	.1038	.331	.1504
24	48.62	24.03	22.13	.27	.47	.68	---	.1654	.0766	.358	.1630
24	48.62	24.55	22.11	.18	.43	.68	---	.1614	.0734	.375	.1707
24	48.62	24.55	21.54	.22	.44	.66	.26	.1614	.0714	.367	.1623
24	64.18	16.62	29.02	1.21	1.38	1.55	.92	.4648	.2102	.337	.1523
24	64.18	20.52	28.88	.61	.81	1.02	.59	.3048	.1372	.376	.1694
24	64.18	23.61	29.06	.41	.61	.80	.44	.2302	.1042	.377	.1708
24	64.18	24.49	28.96	.36	.60	.83	.41	.2140	.0966	.357	.1610
24	79.74	20.52	35.45	.92	1.14	1.36	.72	.3788	.1684	.332	.1477
24	79.74	20.58	36.24	.95	1.14	1.33	.76	.3766	.1712	.330	.1502
24	79.74	20.61	35.96	.95	1.15	1.36	.71	.3754	.1692	.326	.1471
24	79.74	22.95	35.80	.68	.86	1.05	.57	.3028	.1360	.352	.1581
24	79.74	23.04	35.55	.68	.89	1.09	.55	.3004	.1340	.276	.1229
24	79.74	23.04	35.95	.73	.92	1.12	.54	.3004	.1354	.326	.1472
24	79.74	24.52	36.23	.53	.72	.91	---	.2652	.1204	.368	.1672
24	79.74	24.58	35.21	.53	.74	.95	.48	.2640	.1166	.357	.1576
24	79.74	24.78	35.86	.53	.76	.99	.42	.2596	.1169	.342	.1537
30	1.94	2.86	1.08	1.15	1.29	1.44	.82	.4744	.2641	.368	.2047

TABLE II - Concluded

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 40° ANGLE OF DEAD RISE AND VERTICAL CHINE STRIPS - LANGLEY TANK MODEL 277B

Trim, τ, deg	C_Δ	C_V	C_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_S}	C_{D_S}
30	1.94	3.15	1.07	0.97	1.11	1.26	0.83	0.3912	0.2158	0.352	0.1944
30	1.94	3.19	1.14	.70	.86	1.02	---	.3812	.2240	.443	.2605
30	1.94	4.06	1.07	.44	.60	.78	---	.2354	.1298	.392	.2163
30	1.94	4.75	1.16	.29	.47	.63	0.34	.1720	.1028	.366	.2187
30	5.84	5.48	3.37	.90	1.05	1.21	.60	.3890	.2244	.370	.2137
30	5.84	5.58	3.41	.80	.93	1.07	.69	.3750	.2190	.403	.2355
30	5.84	7.06	3.41	.46	.60	.73	.42	.2344	.1368	.391	.2280
30	5.84	9.95	3.30	.07	.27	.46	.29	.1180	.0666	.437	.2467
30	5.84	12.41	3.46	.10	.24	.39	.20	.0758	.0450	.316	.1875
30	9.72	9.16	5.66	.41	.57	.73	.44	.2316	.1348	.406	.2365
30	9.72	10.52	5.66	.27	.41	.56	---	.1756	.1022	.428	.2493
30	17.50	8.62	10.25	1.04	1.20	1.36	.82	.4710	.2760	.392	.2300
30	17.50	9.55	10.18	.83	.95	1.07	.66	.3838	.2232	.404	.2349
30	17.50	12.16	10.08	.44	.59	.75	.37	.2366	.1364	.401	.2312
30	17.50	12.19	10.12	.44	.58	.73	.43	.2356	.1362	.406	.2348
30	17.50	12.25	10.00	.41	.55	.68	---	.2332	.1332	.424	.2422
30	17.50	17.28	10.23	.12	.32	.51	.32	.1172	.0684	.366	.2138
30	25.28	14.78	14.53	.44	.60	.73	.40	.2314	.1330	.386	.2217
30	25.28	17.34	14.64	.24	.41	.58	.35	.1682	.0974	.410	.2376
30	25.28	20.52	14.86	.10	.29	.49	.23	.1200	.0706	.414	.2434
30	25.28	20.67	14.68	.10	.28	.46	.17	.1184	.0688	.423	.2457
30	33.06	11.87	19.15	1.07	1.18	1.28	.80	.4692	.2718	.398	.2303
30	33.06	13.16	19.06	.80	.95	1.09	.65	.3818	.2200	.402	.2316
30	33.06	14.73	19.08	.58	.75	.92	.52	.3048	.1758	.406	.2344
30	33.06	19.62	19.05	.24	.40	.56	.26	.1718	.0990	.429	.2475
30	33.06	23.80	19.25	.19	.36	.53	.30	.1168	.0680	.324	.1889
30	33.06	24.55	19.26	.08	.28	.48	.29	.1096	.0640	.391	.2286
30	48.62	14.24	28.16	1.09	1.24	1.38	.71	.4796	.2778	.387	.2240
30	48.62	14.36	28.08	1.04	1.18	1.31	.80	.4716	.2724	.400	.2308
30	48.62	15.99	28.01	.78	.92	1.07	.61	.3804	.2192	.413	.2383
30	48.62	18.08	28.12	.56	.69	.83	.41	.2974	.1720	.431	.2493
30	48.62	20.34	28.04	.44	.58	.73	.35	.2350	.1356	.405	.2338
30	48.62	21.18	28.07	.37	.55	.73	.29	.2168	.1252	.394	.2276
30	48.62	23.80	27.98	.24	.41	.58	.25	.1716	.0988	.418	.2410
30	64.18	16.46	37.10	1.07	1.20	1.33	.74	.4738	.2738	.395	.2282
30	64.18	20.49	37.07	.61	.74	.87	.48	.3058	.1766	.413	.2386
30	64.18	23.46	37.24	.44	.58	.73	.36	.2332	.1354	.402	.2334
30	64.18	24.66	36.87	.36	.51	.66	.31	.2110	.1212	.414	.2376
30	79.74	18.54	45.96	1.07	1.22	1.38	.74	.4640	.2674	.380	.2192
30	79.74	20.49	45.76	.80	.93	1.07	.58	.3798	.2180	.408	.2344
30	79.74	22.89	45.60	.61	.76	.92	.45	.3044	.1740	.400	.2289
30	79.74	24.69	45.96	.44	.62	.80	.39	.2616	.1508	.422	.2432

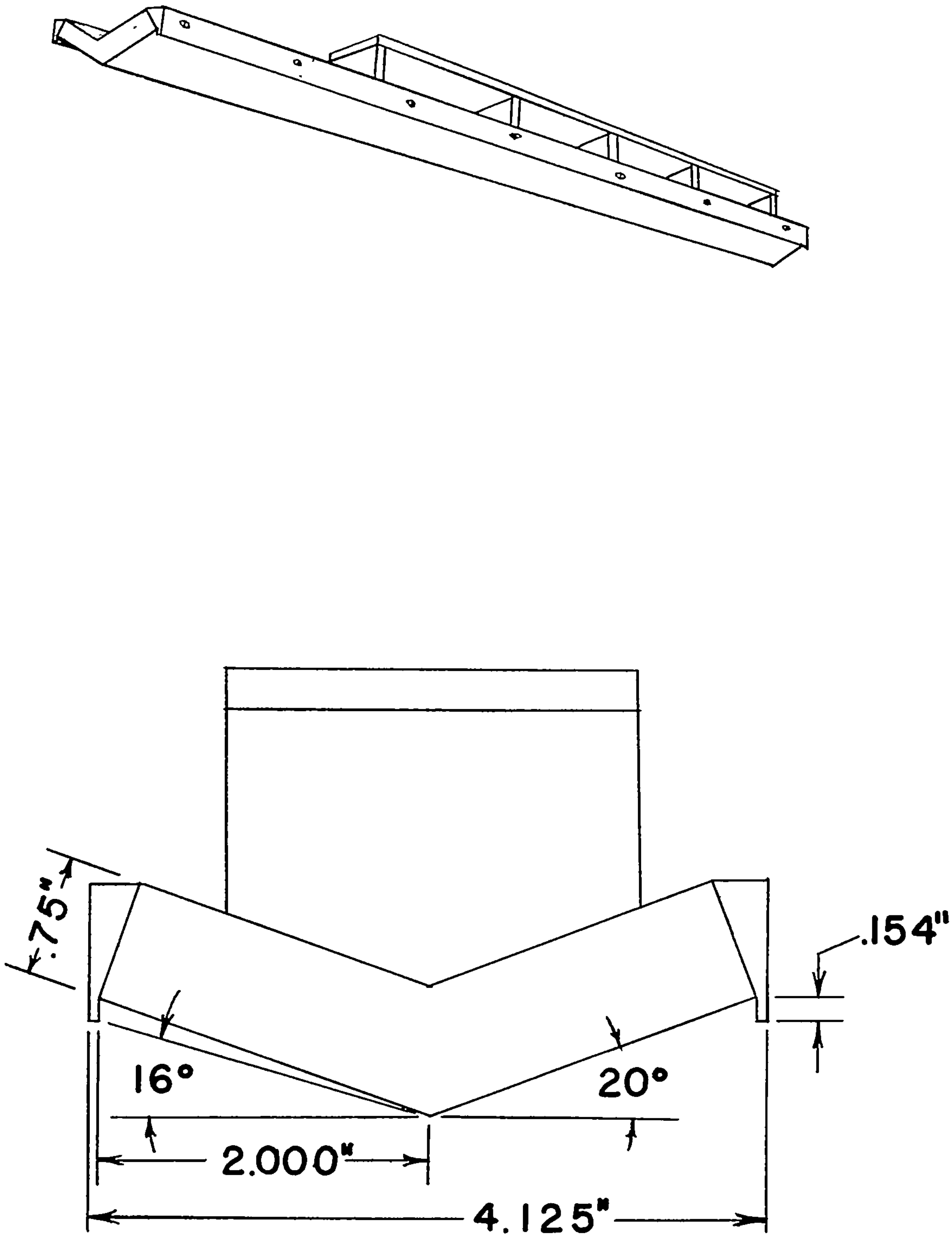

Figure 1.- Sketch and cross section of Langley tank model 276B.

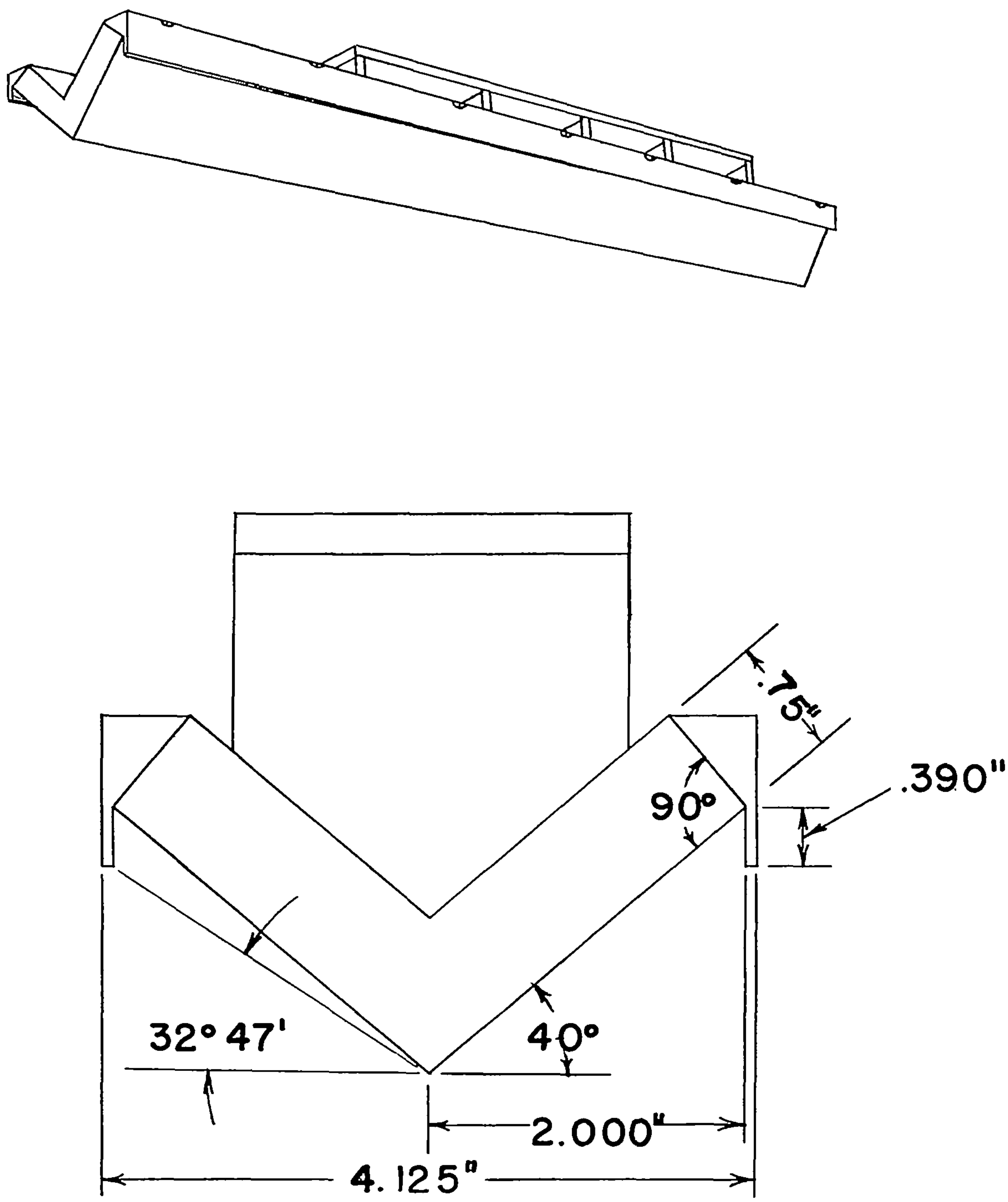

Figure 2.- Sketch and cross section of Langley tank model 277B.

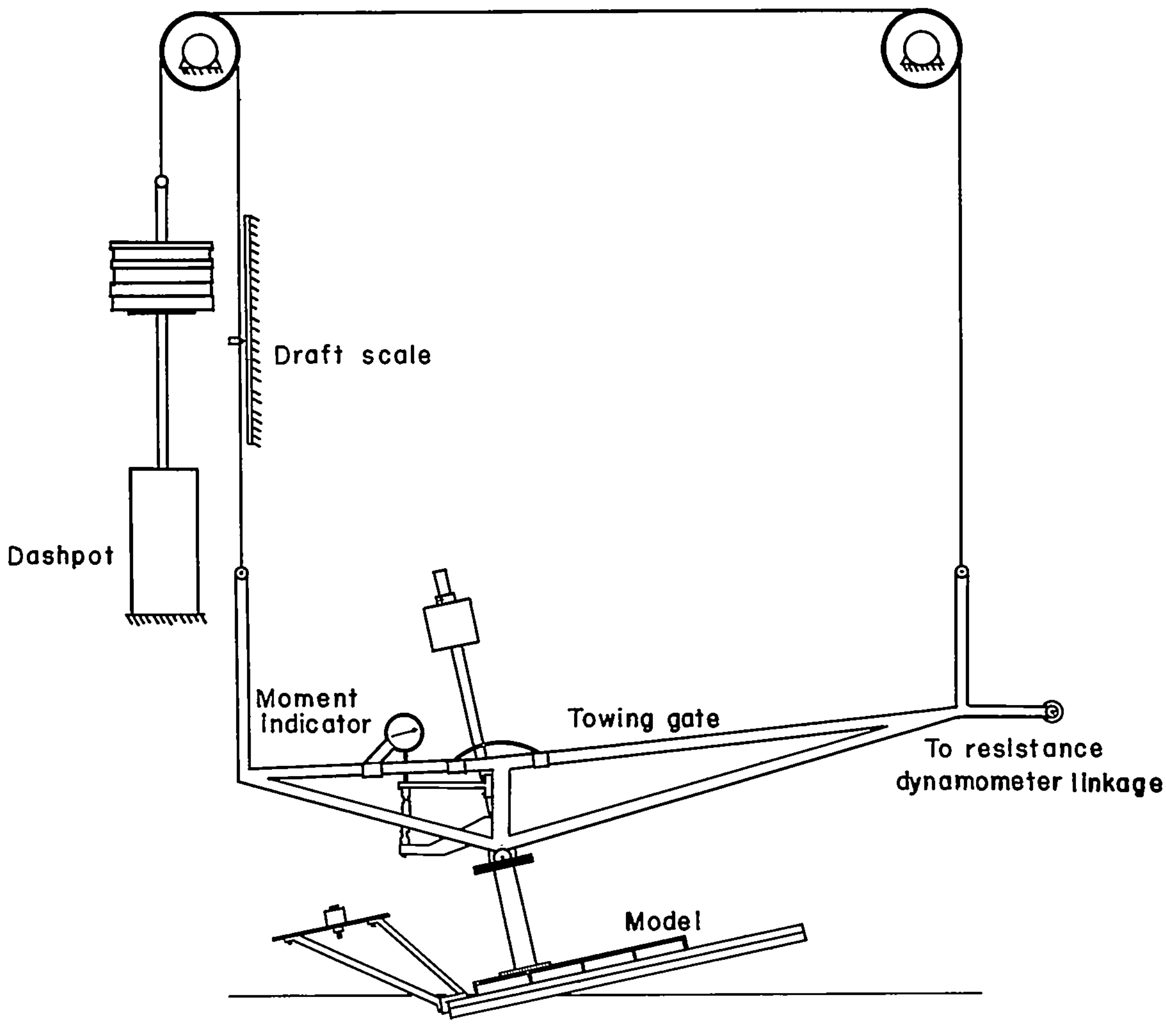

Figure 3.- Setup of model and towing gear.

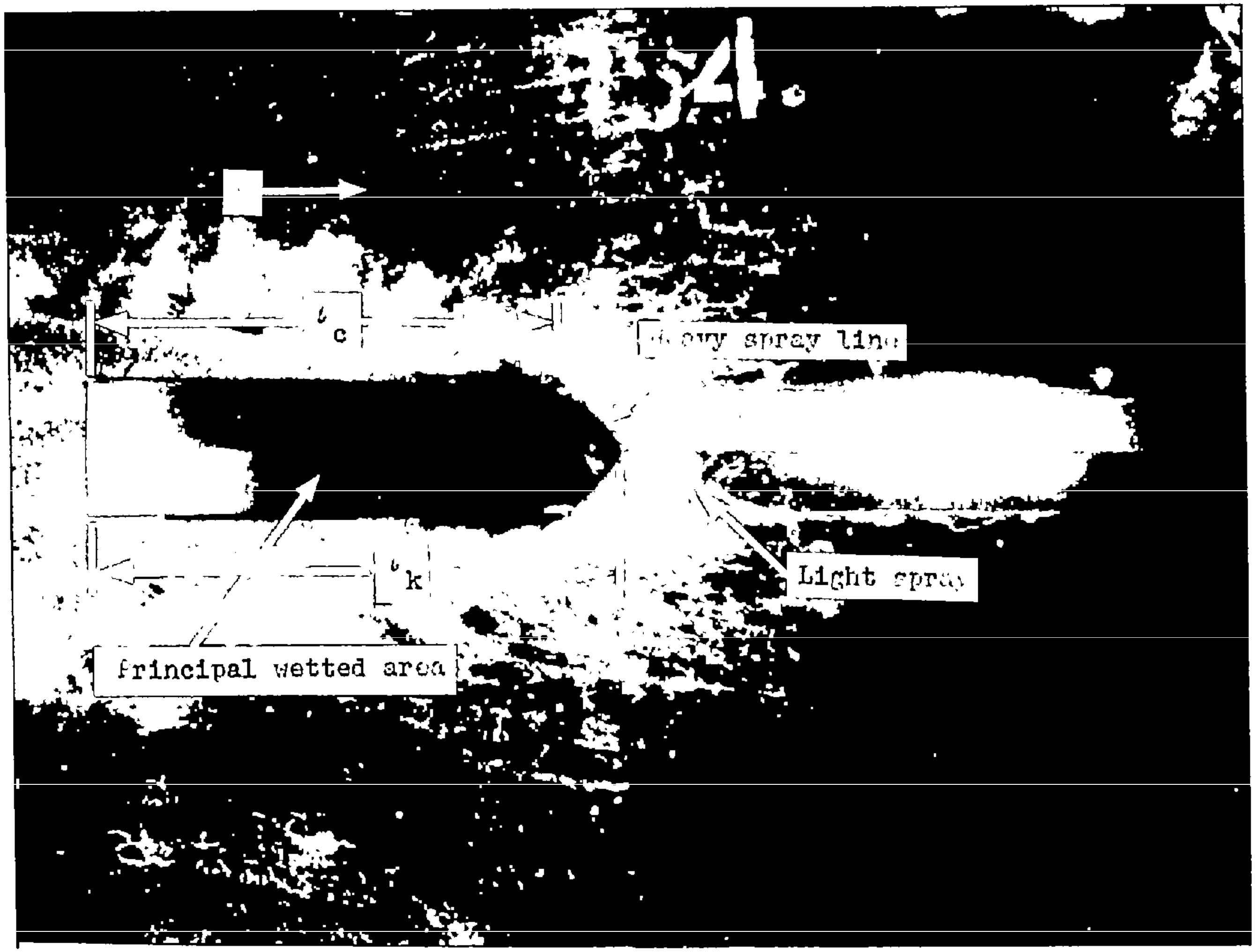

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Figure 4.- Typical underwater photograph.

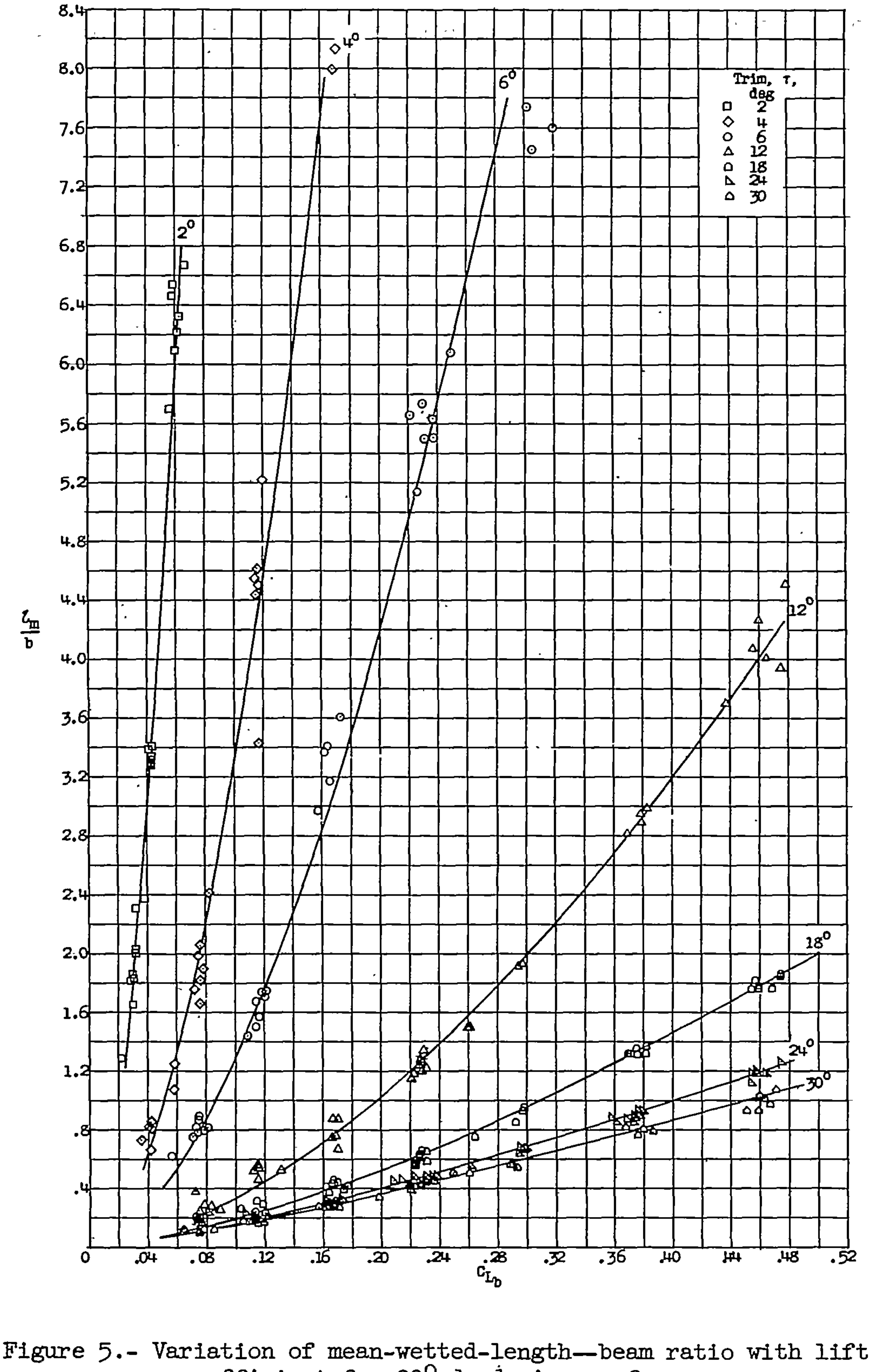


Figure 5.- Variation of mean-wetted-length—beam ratio with lift coefficient for 20° dead-rise surface.

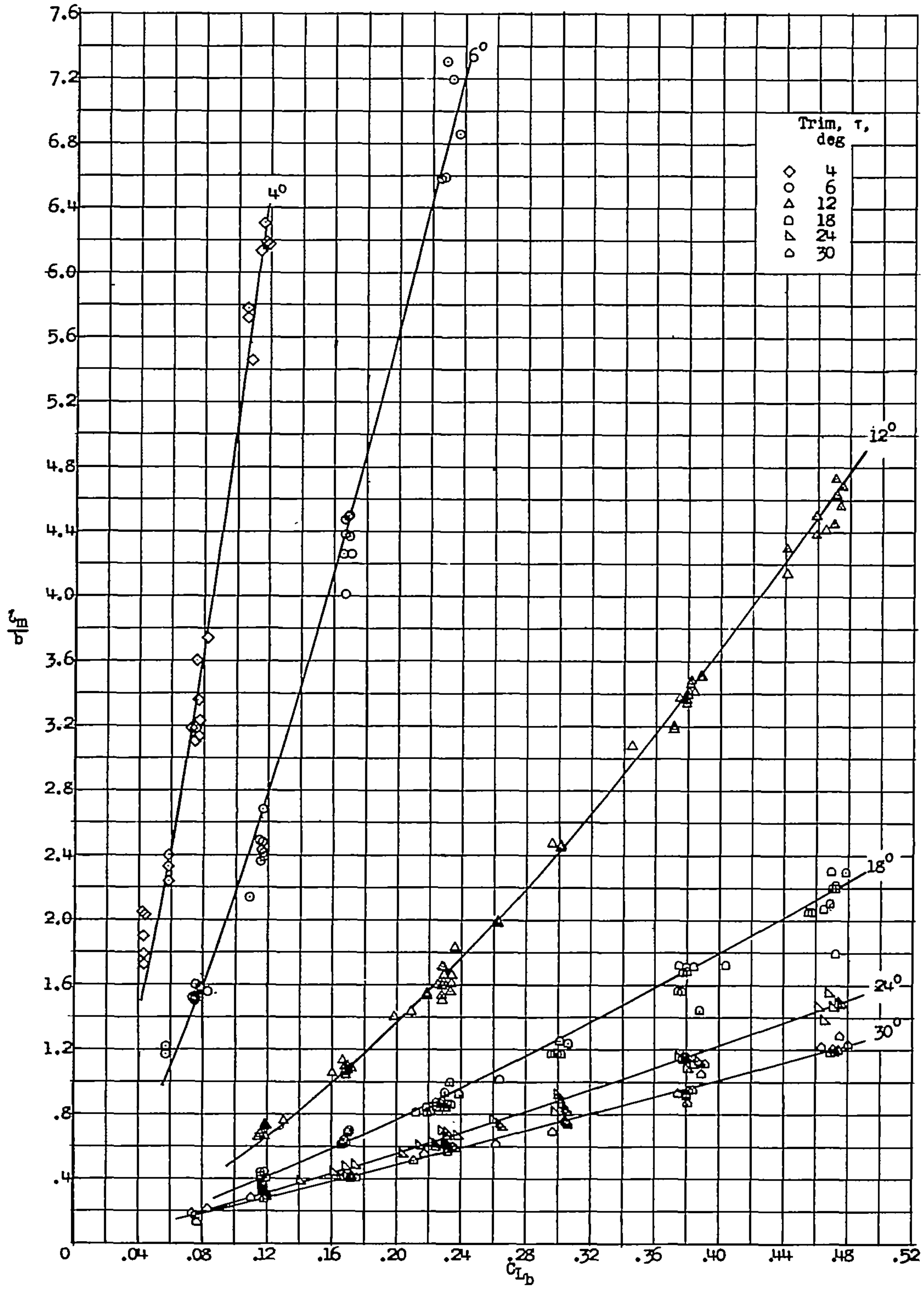


Figure 6.- Variation of mean-wetted-length—beam ratio with lift coefficient for 40° dead-rise surface.

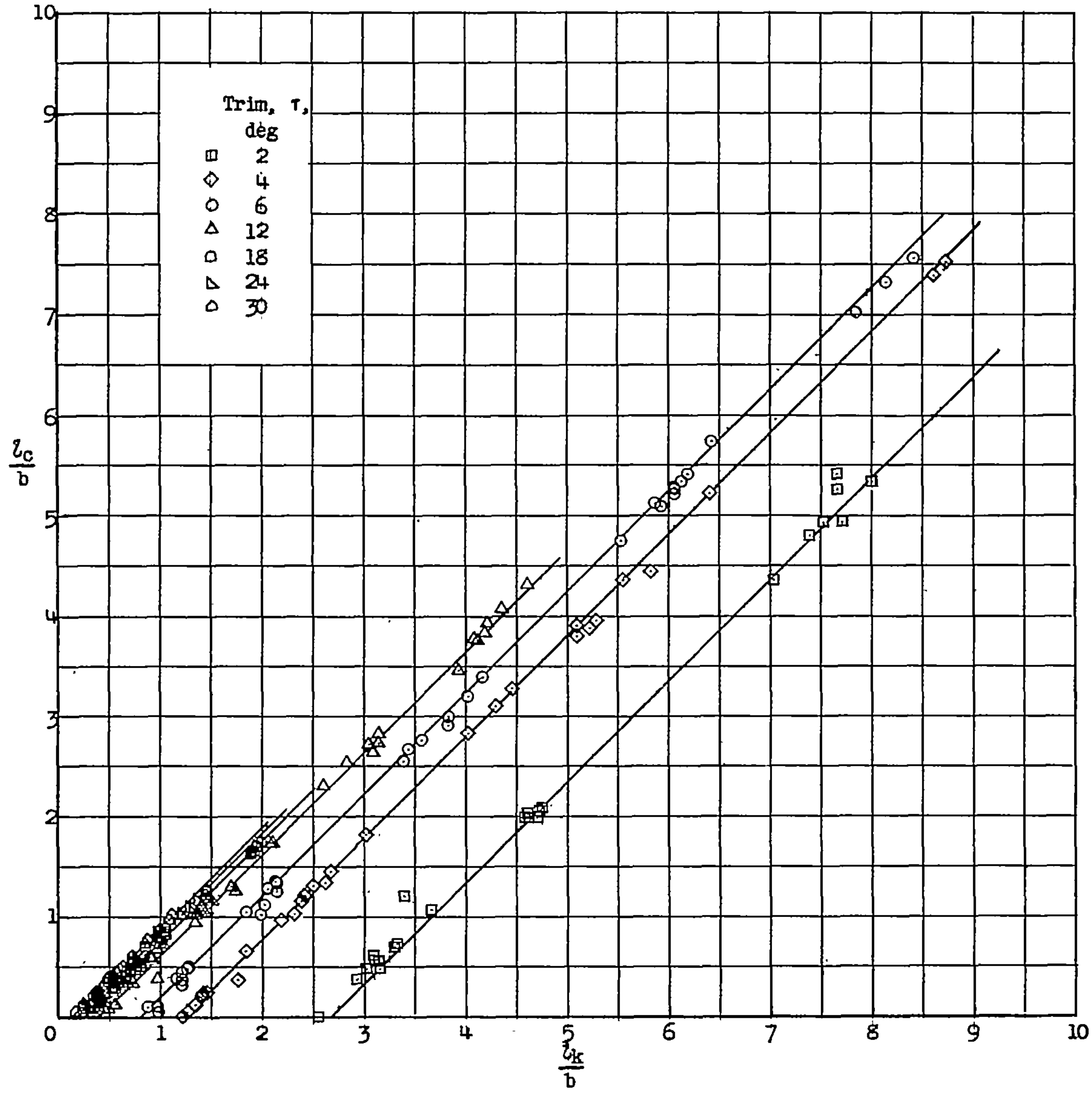


Figure 7.- Variation of chine-wetted-length—beam ratio with keel-wetted-length—beam ratio for 20° dead-rise surface.

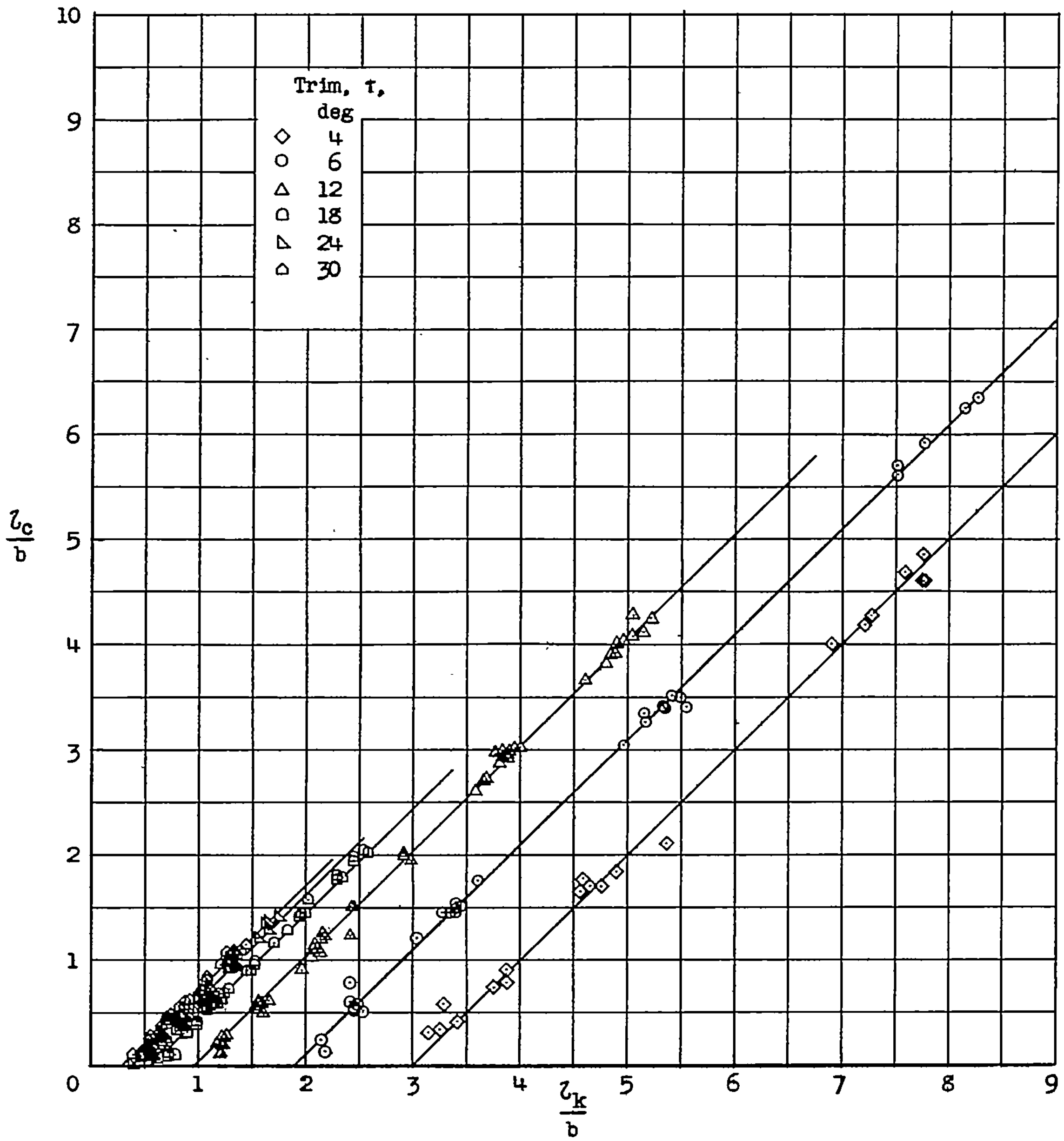


Figure 8.- Variation of chine-wetted-length—beam ratio with keel-wetted-length—beam ratio for 40° dead-rise surface.

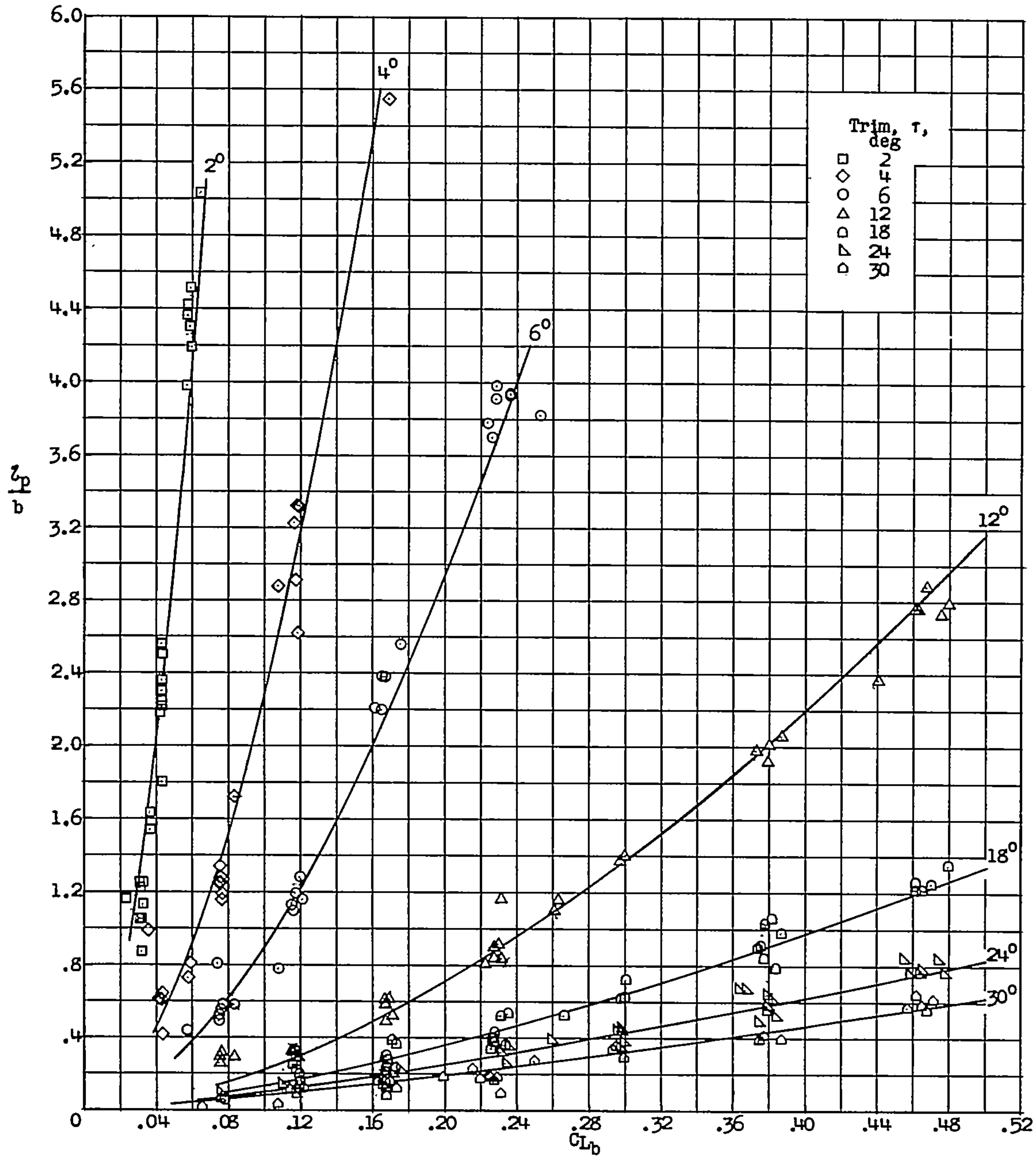


Figure 9.- Variation of center-of-pressure location with lift coefficient for 20° dead-rise surface.

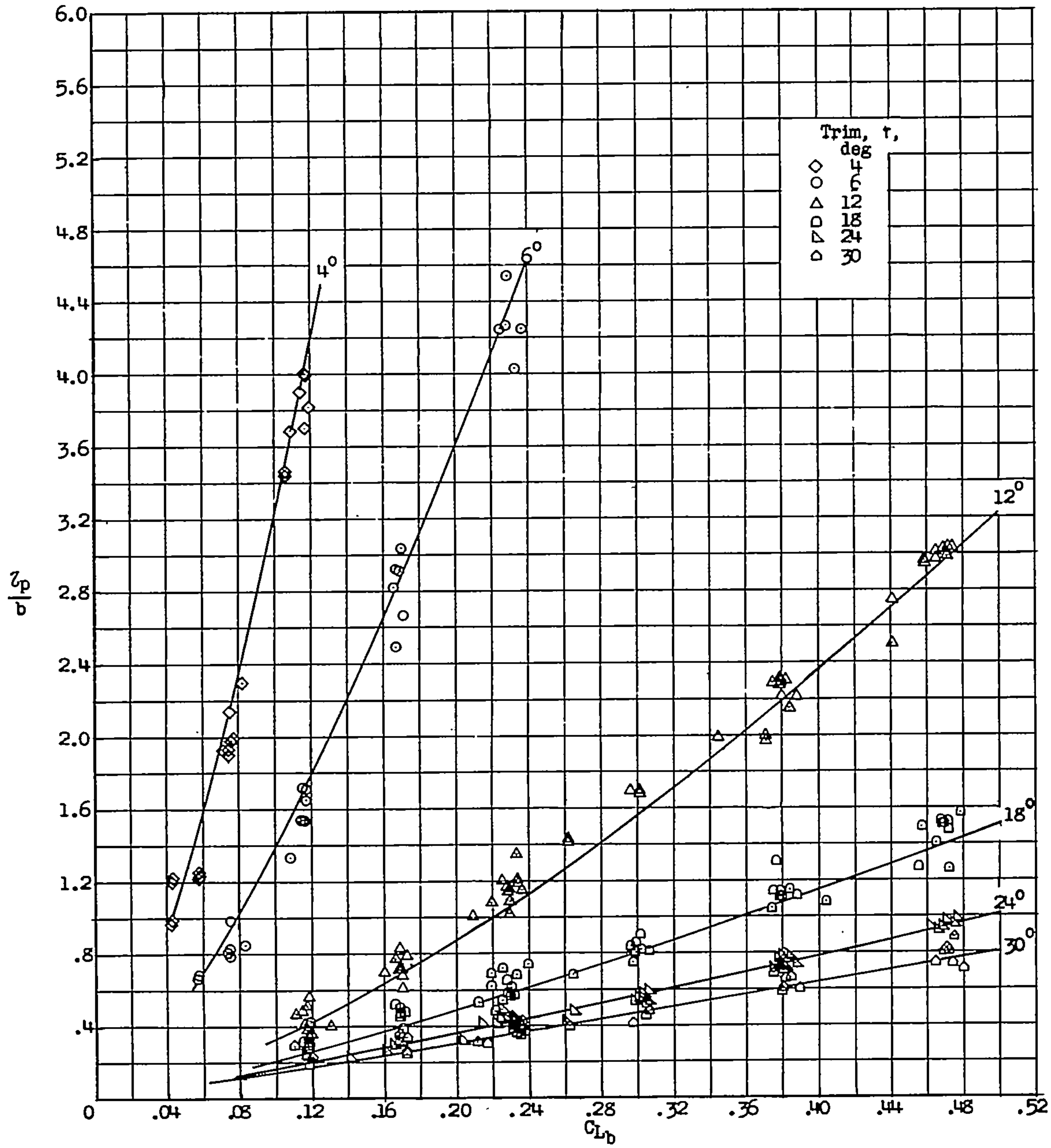


Figure 10.- Variation of center-of-pressure location with lift coefficient for 40° dead-rise surface.

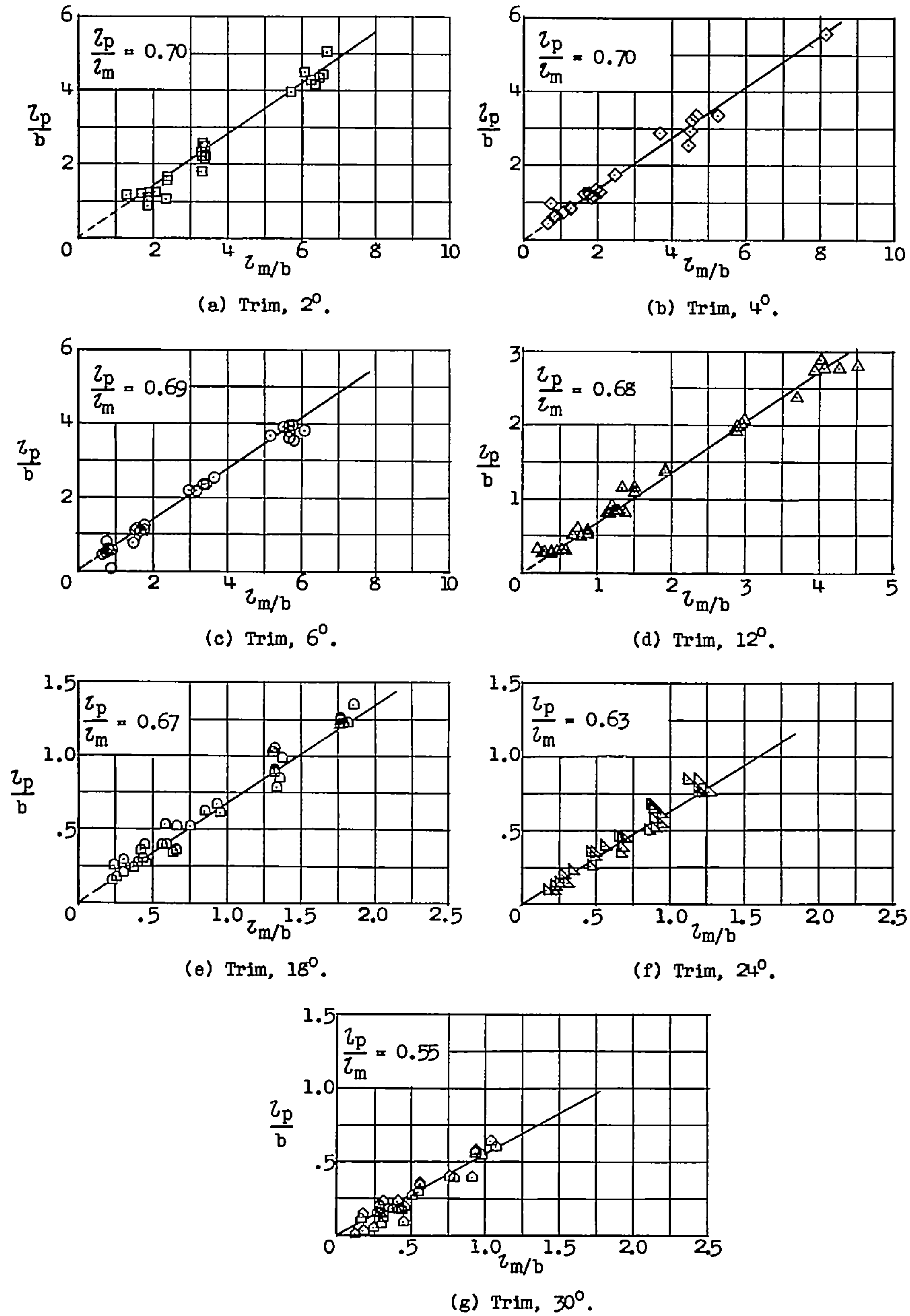


Figure 11.- Variation of center-of-pressure ratio with mean-wetted-length–beam ratio for 20° dead-rise surface.

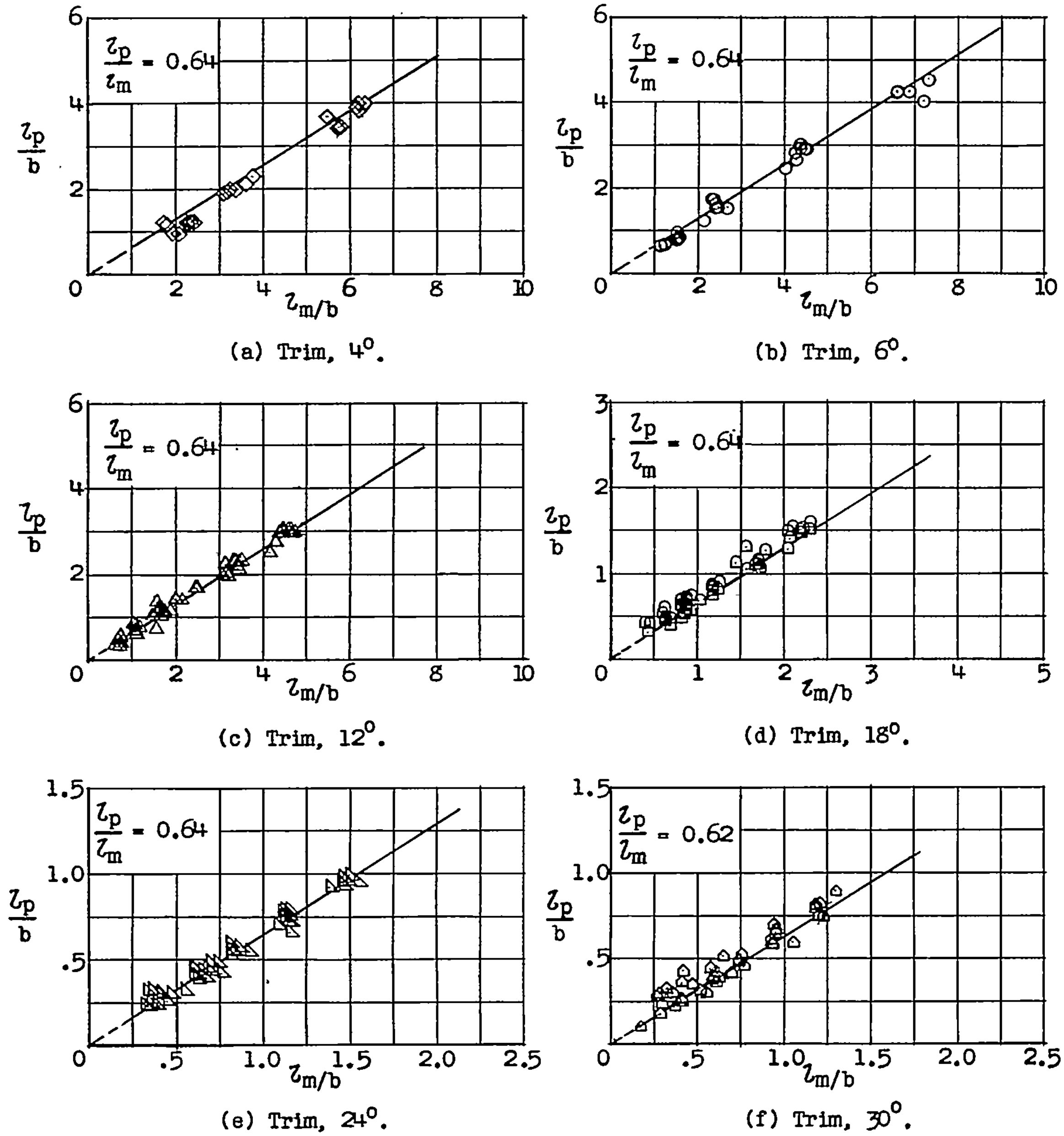
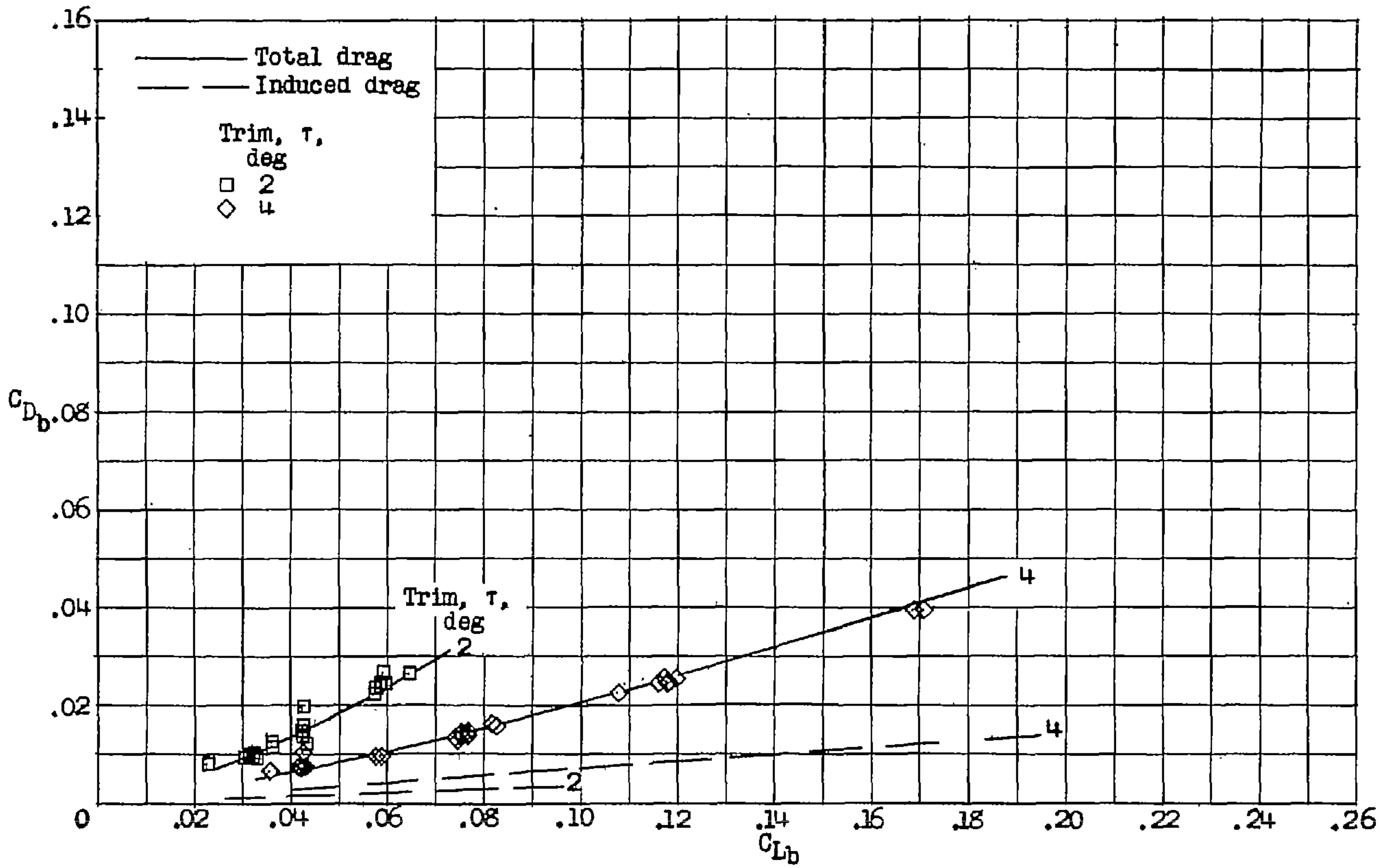
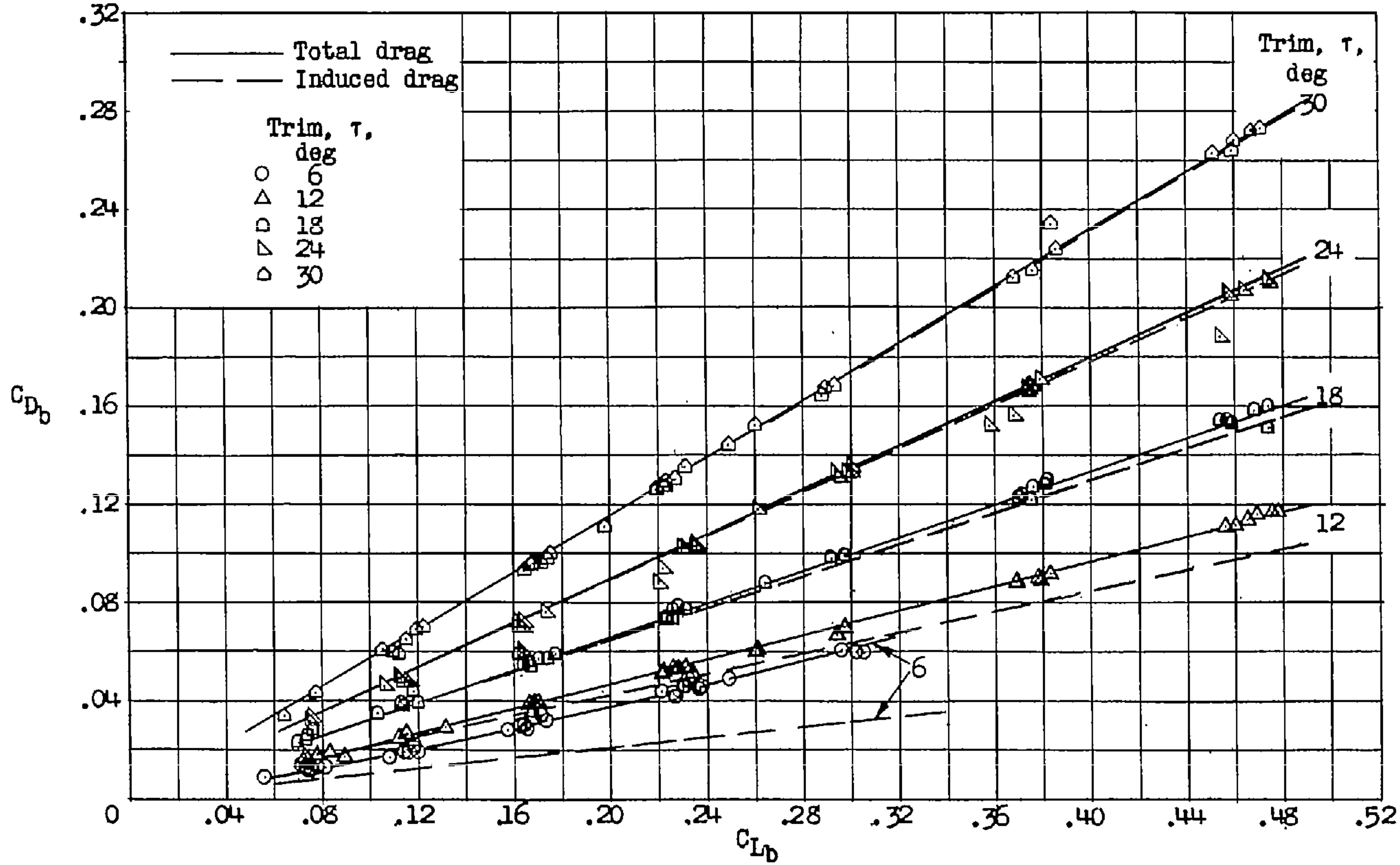


Figure 12.- Variation of center-of-pressure ratio with mean-wetted-length—beam ratio for 40° dead-rise surface.



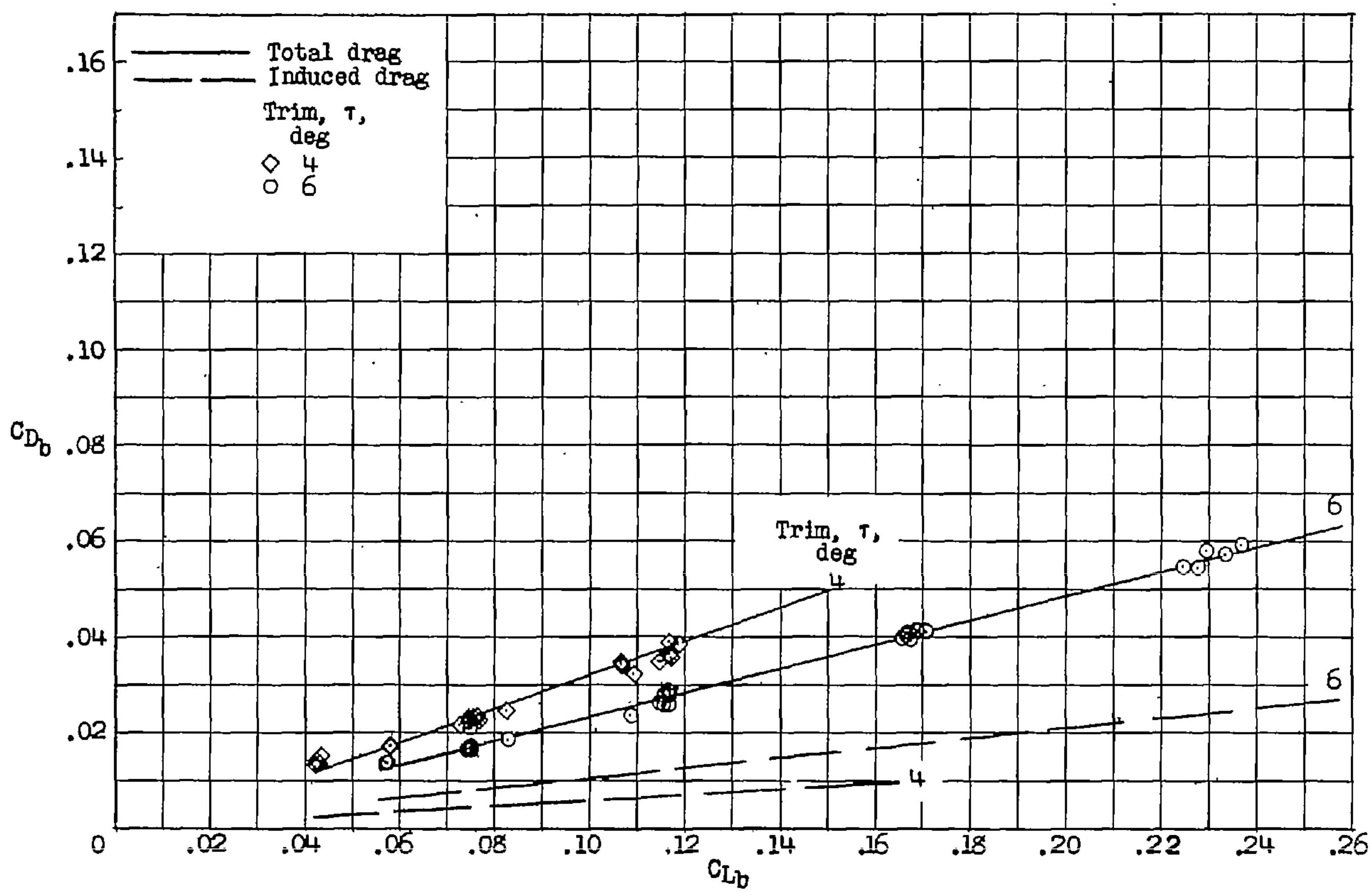
(a) Trim, 2° and 4°.

Figure 13.- Variation of drag coefficient with lift coefficient for 20° dead-rise surface.



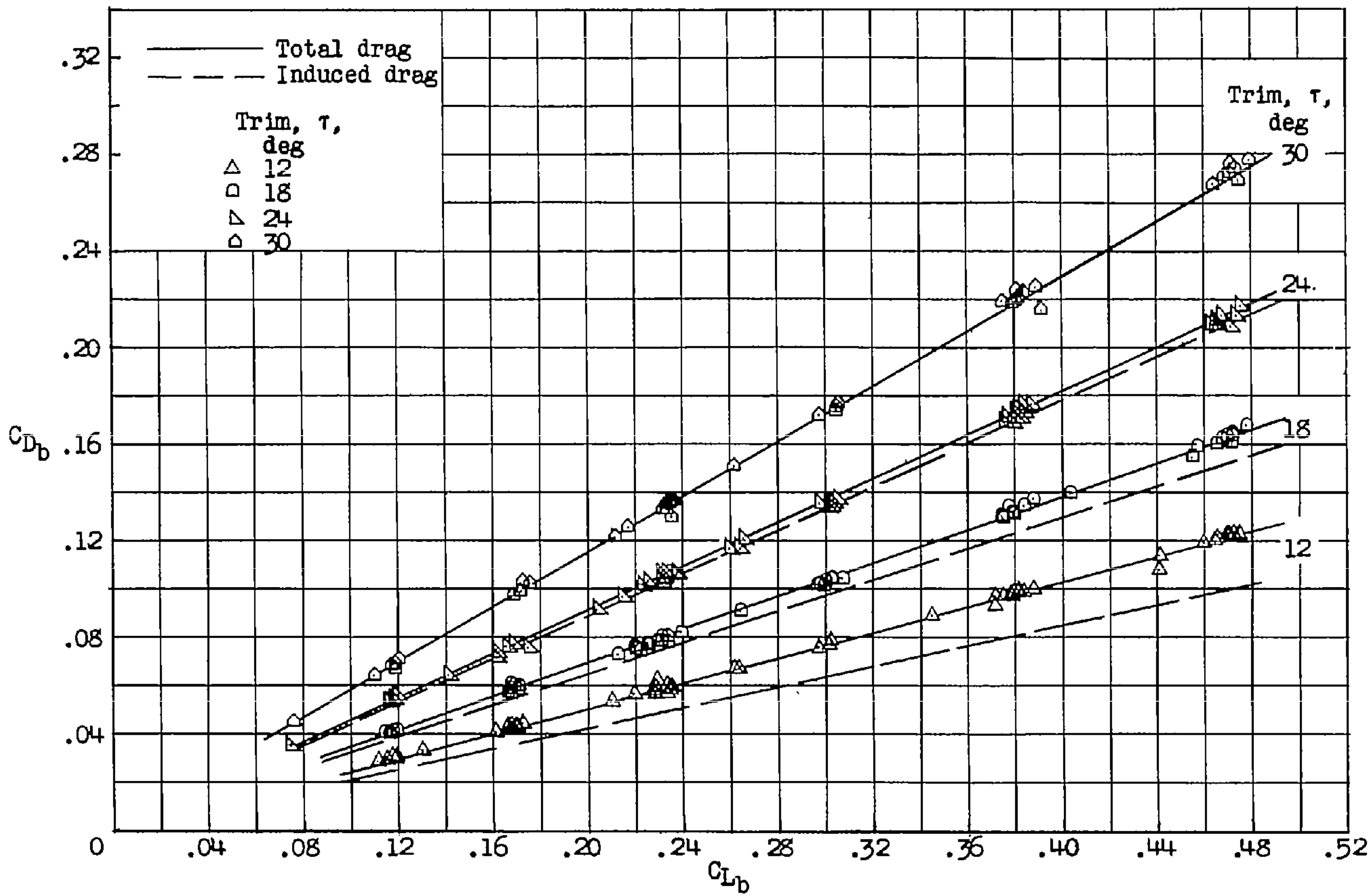
(b) Trim, 6°, 12°, 18°, 24°, and 30°.

Figure 13.- Concluded.



(a) Trim, 4° and 6°.

Figure 14.- Variation of drag coefficient with lift coefficient for 40° dead-rise surface.



(b) Trim, 12°, 18°, 24°, and 30°.

Figure 14.- Concluded.

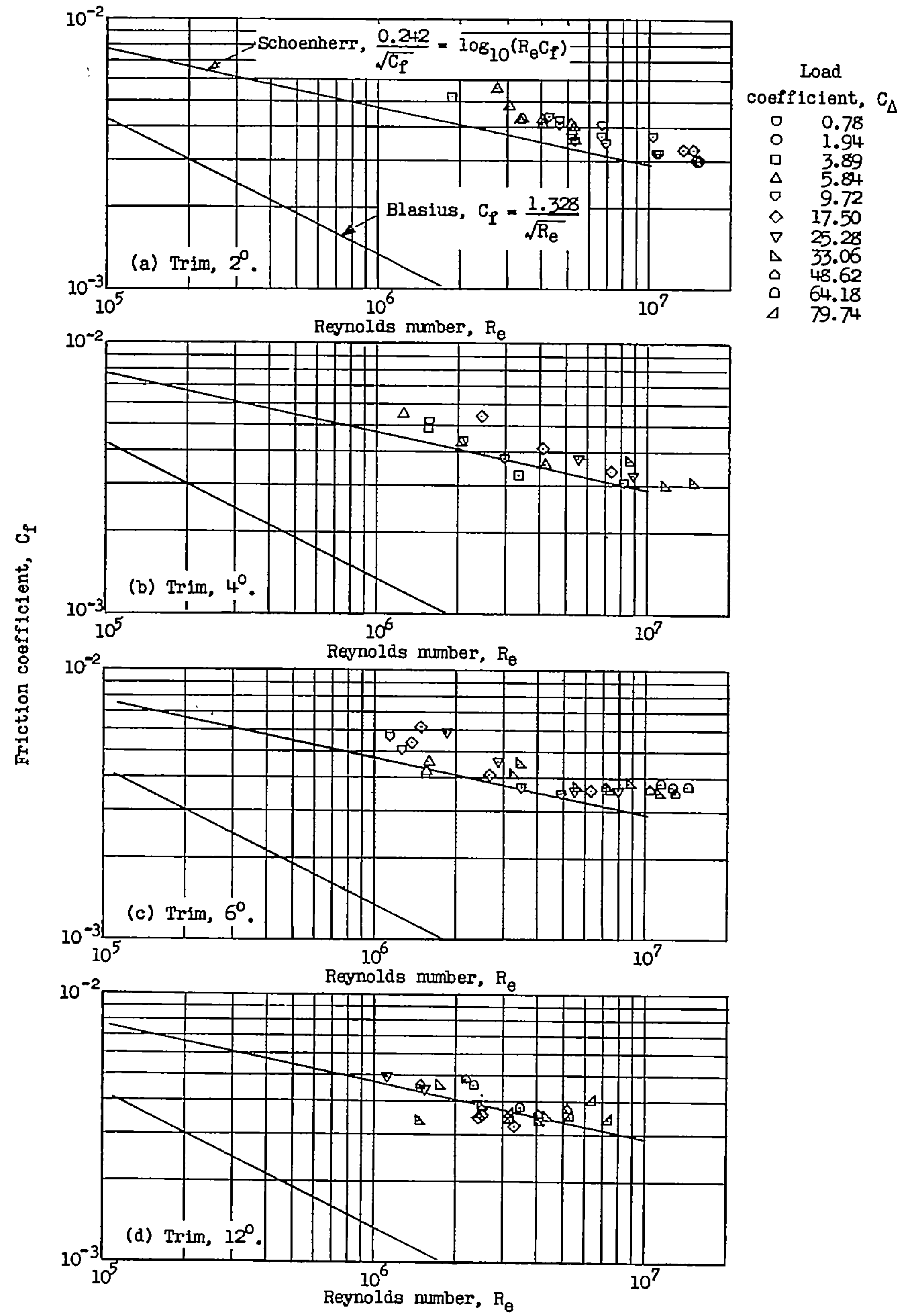


Figure 15.- Variation of friction coefficient with Reynolds number for 20° dead-rise surface.

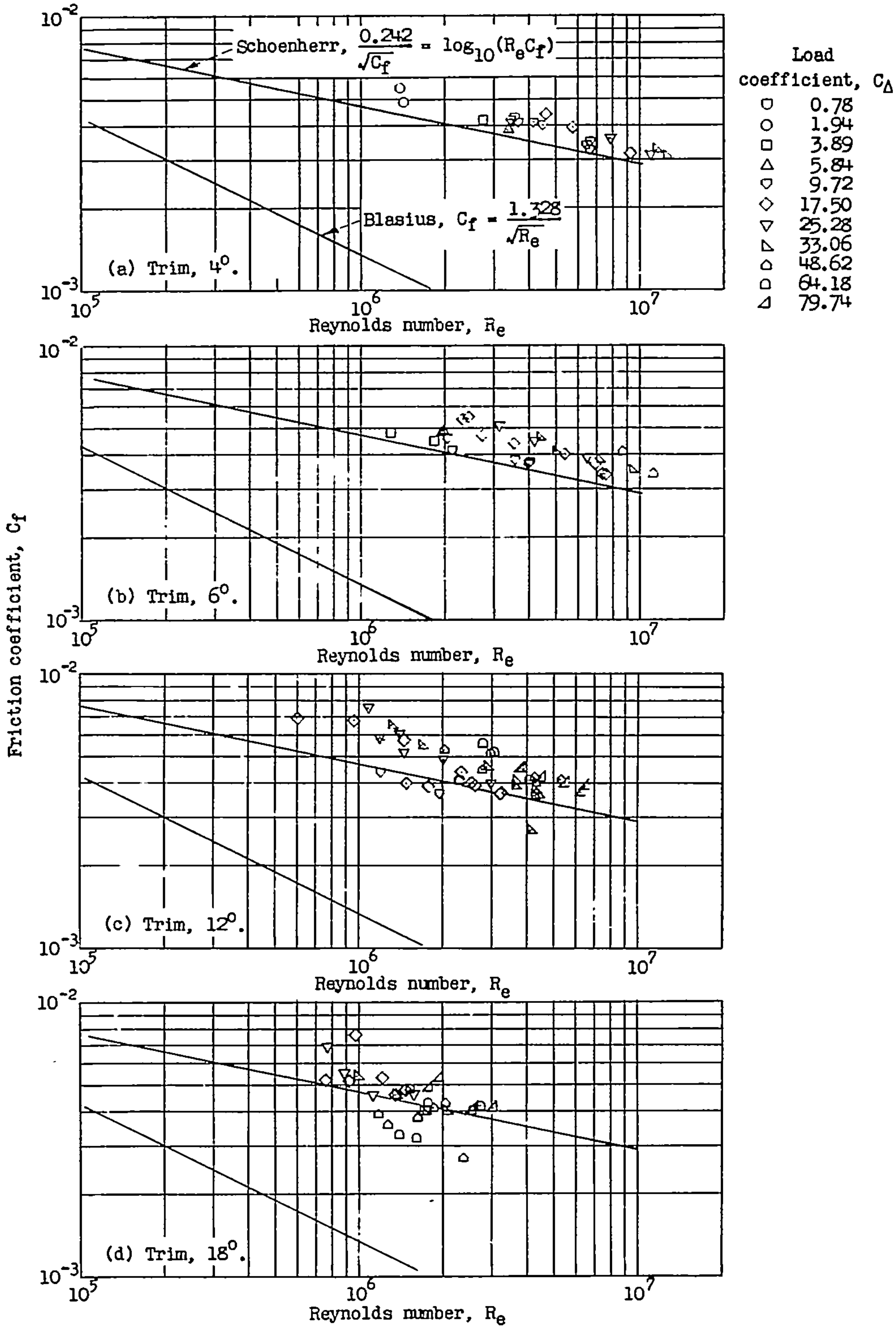
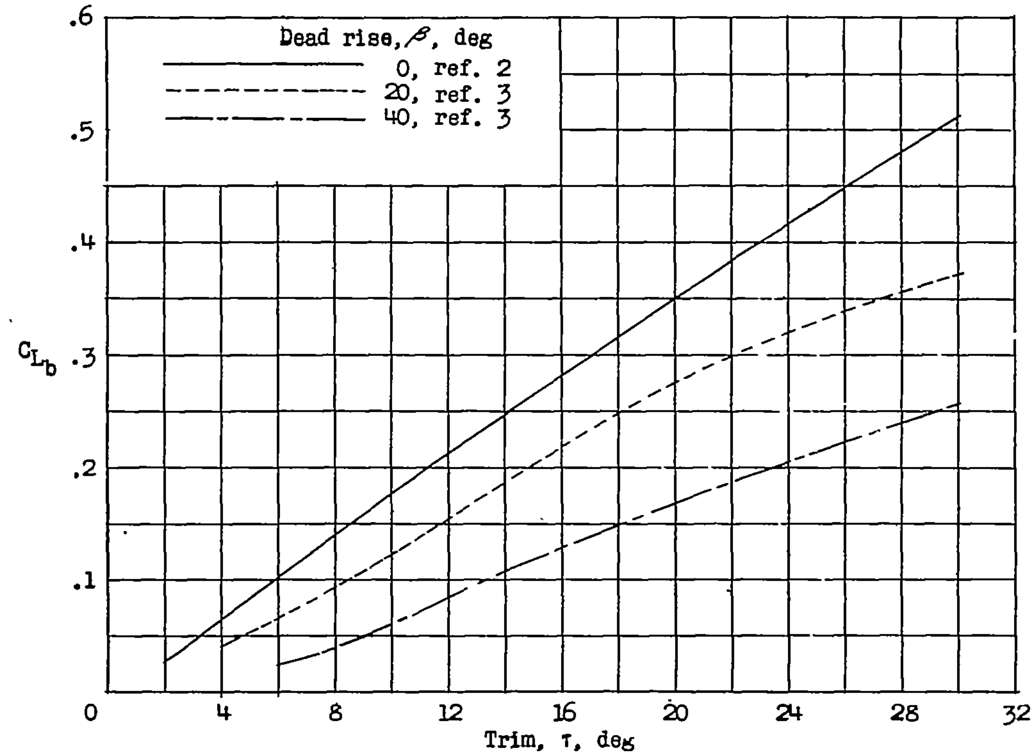
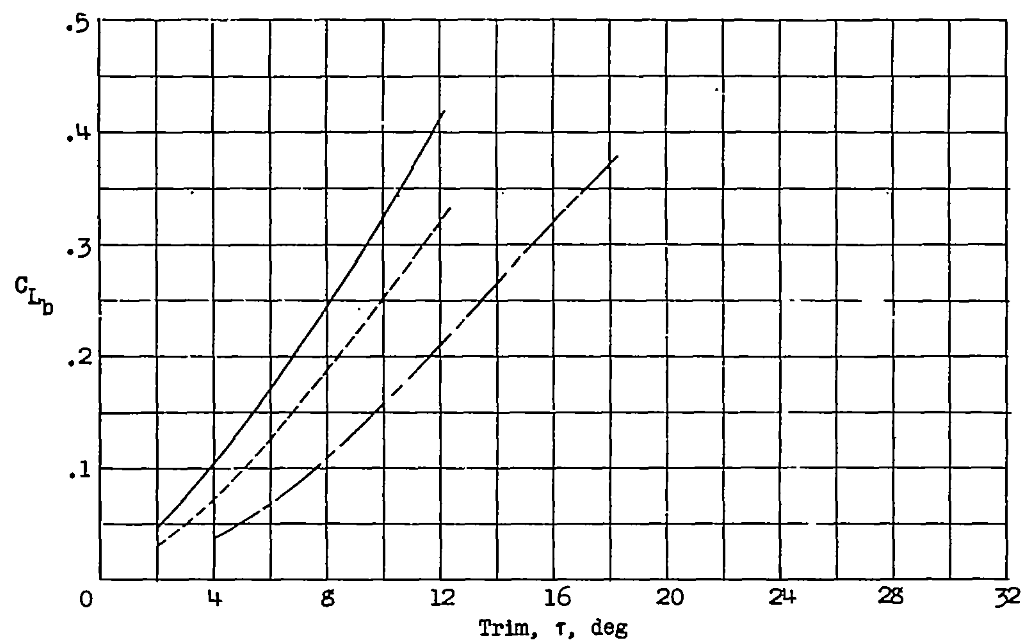


Figure 16.- Variation of friction coefficient with Reynolds number for 40° dead-rise surface.



(a) $\frac{l_m}{b} = 1.0.$



(b) $\frac{l_m}{b} = 3.0.$

Figure 17.- Comparison of the effect of increase in angle of dead rise on the variation of lift coefficient with trim.

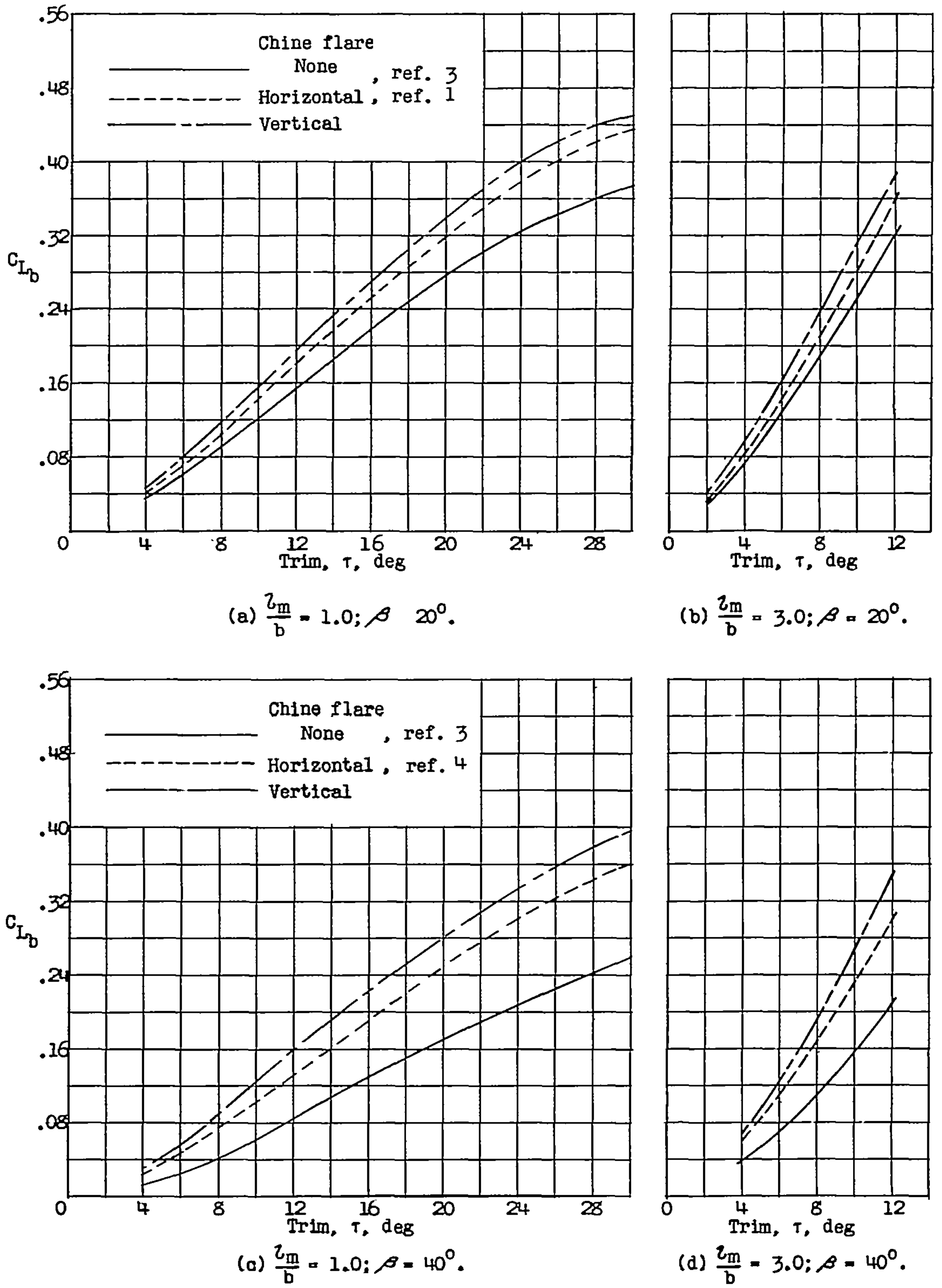
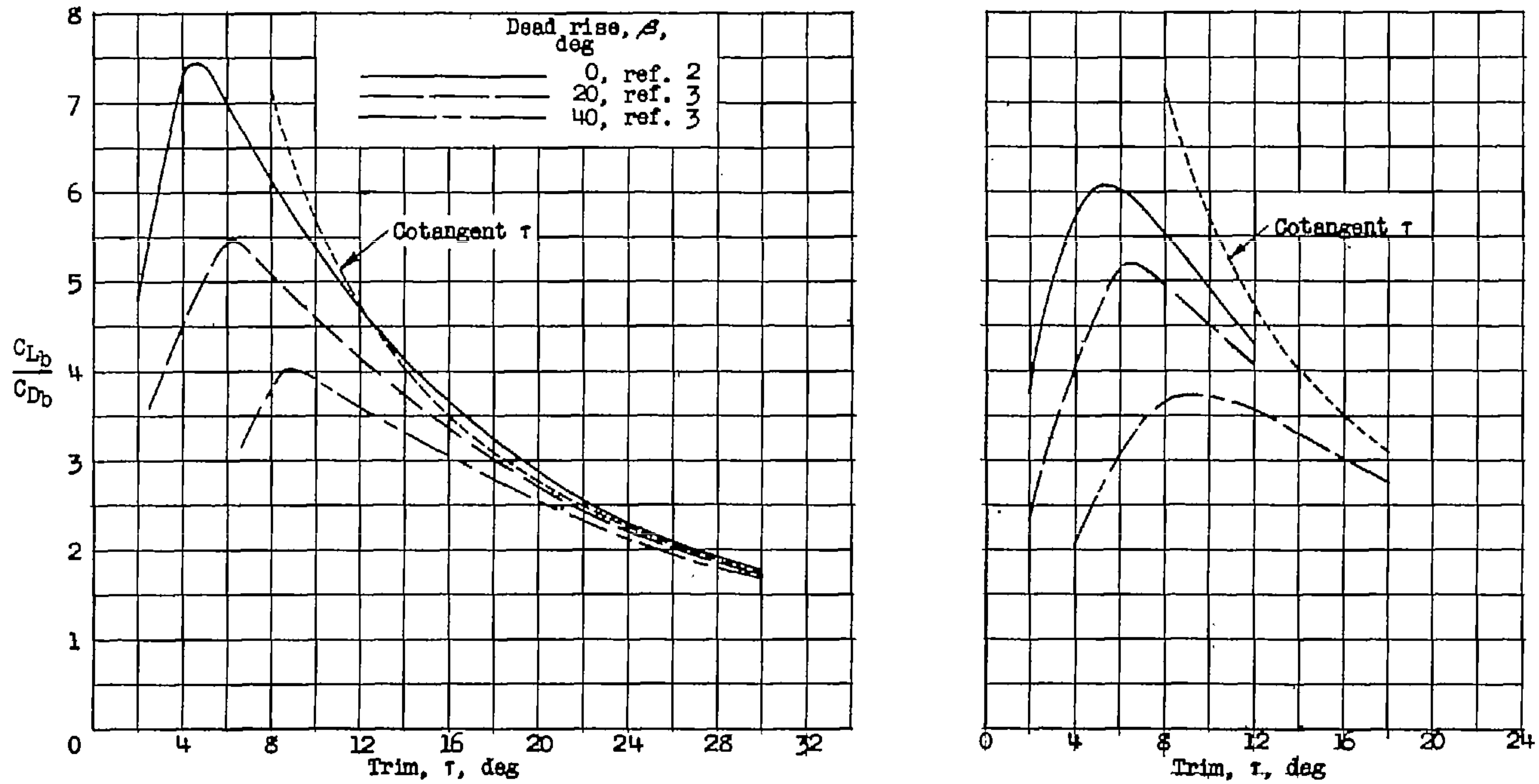


Figure 18.- Comparison of the effect of horizontal and vertical chine flare on the variation of lift coefficient with trim.



(a) $\frac{2m}{b} = 1.0$.

(b) $\frac{2m}{b} = 3.0$.

Figure 19.- Comparison of the effect of increase in angle of dead rise on the lift-drag ratio of a prismatic surface.

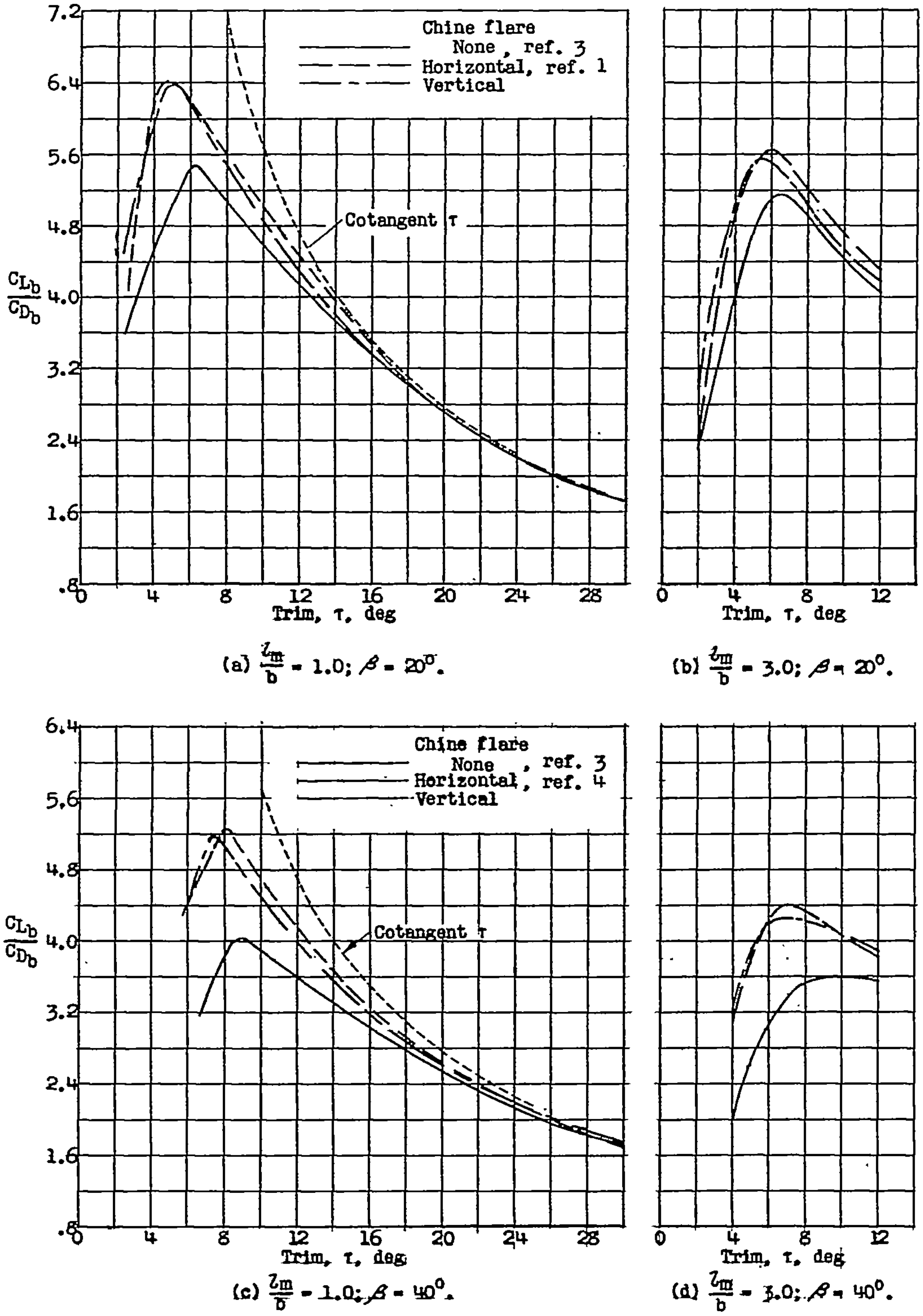


Figure 20.- Comparison of the effect of horizontal and vertical chine flare on the lift-drag ratio of a prismatic surface.

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